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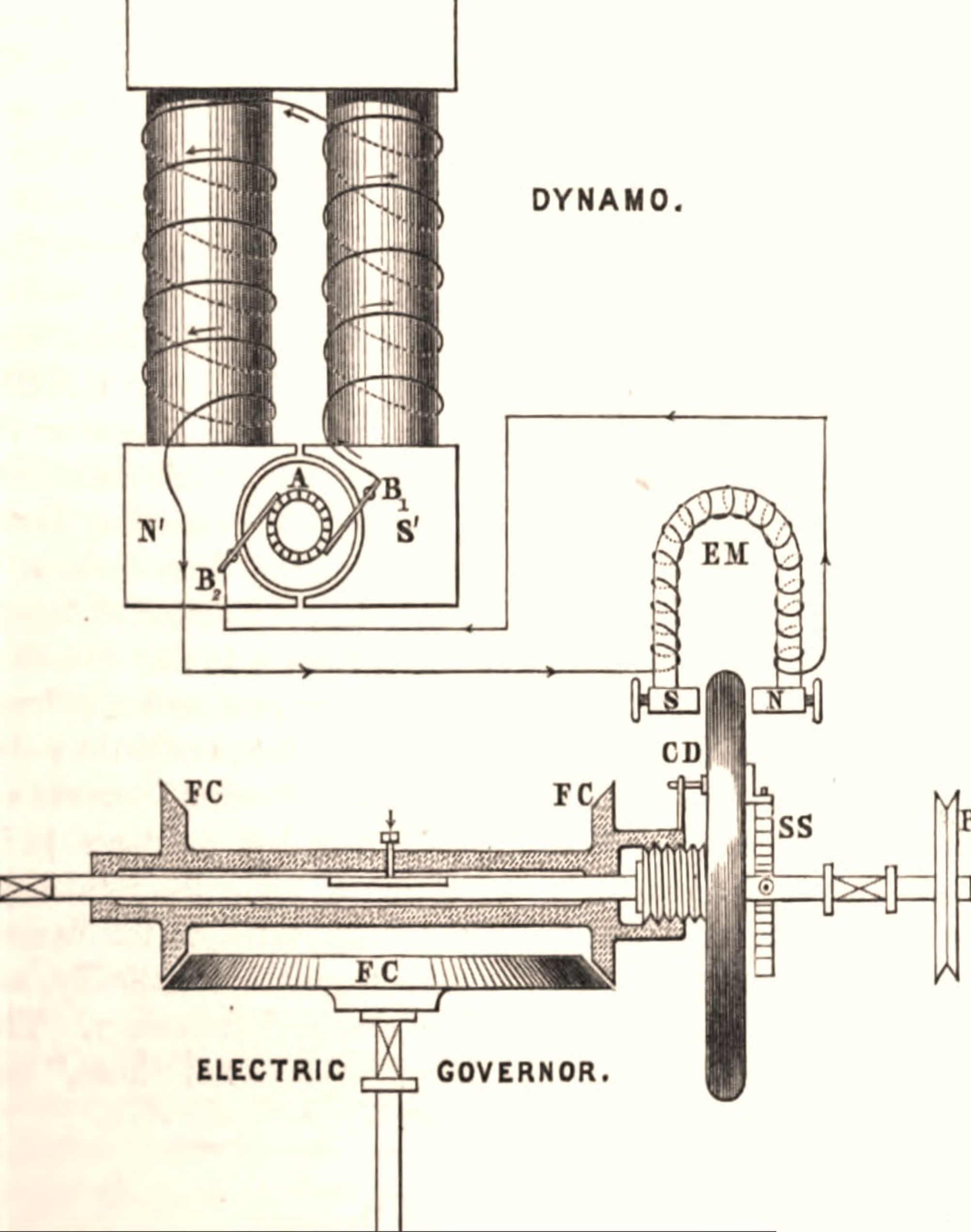
DYNAMO.
A
B_1
N′
S′
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EM
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N
CD
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SS
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ELECTRIC GOVERNOR.

Minutes of Proceedings of the Institution of Civil Engineers; ...

Soc. 18611 e. $\frac{156}{79}$

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXXIX.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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ERRATA.

Vol. xliv., p. 28, line 4, *for* "$\frac{0\cdot0765}{5\cdot2} = 68$" *read* "$\frac{5\cdot2}{0\cdot0765} = 68$."

„ „ p. 33, line 5, *for* "3,696" *read* "36,960."

„ lxxvii., p. 307, lines 6, 24, and 29, *for* "S_1O_2" *read* "Si O_2."

„ lxxviii., p. 132, line 9, *for* "xxii" *read* "xvii."

„ lxxix., p. 2, line 21, *for* "Plate 2, Fig. 2" *read* "Plate 1, Fig. 2."

„ „ p. 113, line 9, *for* "in this way is shown on the opposite page" *read* "as shown by Fig. 3 (p. 110) is given on p. 114."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1884–85.—PART I.

Sect. I.—MINUTES OF PROCEEDINGS.

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11 November, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair.

(*Paper No. 2029.*)

"Electric Lighting for Steamships."

By Andrew Jamieson, Assoc. M. Inst. C.E. and F.R.S.E.

Although it is not more than three years since the first application of incandescent electric lighting to the general illumination of steamships, the advantages accruing therefrom have been so fully recognised, that already more than one hundred and fifty ships have been fitted with it, and scarcely a man-of-war or a first-class passenger-steamer now leaves the builder's hands without having it on board. This rapid success is mainly due to the following causes:—

I. Electric lighting on the incandescent system, when properly fitted, is more healthful, cooler, more easily handled, and more artistic than other systems of lighting; there is no smell, and no products of combustion to tarnish giltwork; it is more agreeable in every way than any of the older methods of illumination.

II. The danger from fire is less, as neither matches nor lighted tapers are required.

III. The daily cleaning and replenishing of lamps, as well as the keeping in store of highly inflammable oil, paraffin, or candles, can to a great extent be dispensed with.

IV. The expense of maintenance is not much in excess of that of the older methods of illumination (in some cases less), whilst the space occupied by the plant is not great, and its position near to, or in, the engine-room causes no annoyance to passengers.

BEST POSITION FOR THE DYNAMO AND ITS ENGINE.

As the dynamo which furnishes the electricity for feeding the incandescent lamps has to be driven at a uniform velocity, neither the ship's main engines, nor the donkey-, nor winch-engines, are suitable for the purpose. The dynamo must have an engine for itself. It is, in most cases, necessary to place this special engine and the dynamo in such a position that the men on watch at the main engines can, with a minimum of trouble, also attend to the electric plant.

This position, therefore, is naturally somewhere near the starting-platform, and if possible on the ship's floors, so that undue vibration and noise may be avoided. Frequently a convenient recess can be provided, either immediately behind the main starting-platform or opposite to the thrust-block, just outside the screw-shaft-tunnel door (Plate 1, Fig. 1). Only in large installations will it pay to have on board an electrician, solely to attend to the dynamo, its engine, and lamps. In such cases, a convenient and cool position is generally selected between decks, in the same compartment with, or in that next to, the refrigerating machinery, if such should be on board, so that one man may attend to both of these novel appliances (Plate 2, Fig. 2).

Where practicable the axes of dynamos with large, heavy armatures should be placed fore and aft, to obviate as much as possible the effects of gyrostatic action, since the angular velocity due to rolling is greatest athwartship. In dynamos where the weight of the armature, its velocity, and radius of gyration are small, gyrostatic effects will not produce any appreciable increase of pressure on the bearings, whatever the position of the dynamo.

The following formula, kindly supplied by Sir William Thomson, with examples, will render this matter clear:—

$$L = \frac{W\,k^2\,\Omega\,\omega}{g} \text{ and } P = \frac{W\,k^2\,\Omega\,\omega}{g\,l}.$$

Where L = moment of couple on axis.
P = pressure on each bearing.
W = weight of armature.
k = radius of gyration about axis.
$\Omega = \frac{2\,\pi}{T}\,A$ = maximum angular velocity of dynamo in radians[1] per second, due to rolling of ship.
$A = \frac{\pi\,d}{180}$ = amplitude in radians per second.

---

[1] Radian is unit angle in circular measure.

d = degrees of roll from mean position.
T = periodic time in seconds.
$\omega = 2\pi n$ = angular velocity of armature in radians per second.
n = number of revolutions of armature per second.
l = distance between bearings.
g = acceleration due to gravity.

Take the case of a ship rolling 20° from the mean position, with a periodic time of sixteen seconds.

Then $$\Omega = \frac{2\pi A}{T} = \frac{2\pi}{T} \times \frac{\pi d}{180} = \frac{2\pi^2 \times 20}{16 \times 180} = \frac{\pi^2}{72} =$$ 0·137 radian per second.

Examples.

With a Siemens' S D_6 dynamo machine, running at six hundred revolutions per minute, weight of armature 500 lbs., radius of gyration 0·3 foot, and distance between bearings 3·3 feet, the gyrostatic pressure on each bearing only amounts to 3·6 lbs.

With a Siemens (W 16) alternate-current machine, running at thirteen hundred revolutions per minute, weight of armature 148 lbs., radius of gyration 0·7 foot, and distance between bearings 1·4 foot.

Then $$\frac{W k^2 \Omega \omega}{g l} = \frac{148 \times 0{\cdot}7^2 \times 0{\cdot}137 \times 136}{32{\cdot}2 \times 1{\cdot}4} = 30{\cdot}6 \text{ lbs.}$$

To take an extreme case, such as an alternate-current machine, with a heavy armature running at two thousand revolutions per minute, let the weight of armature be 500 lbs., the radius of gyration 1·2 foot, and the angular velocity of ship's roll in radian per second 0·3. If the distance between the bearings were 1·5 foot, there would be a pressure on each bearing of about 930 lbs. Such a dynamo is not likely to be used on board ship.

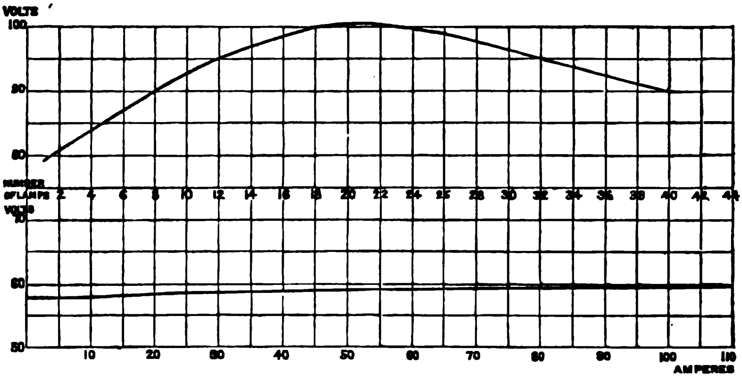
SELECTION OF A DYNAMO

In selecting a dynamo it is necessary to determine whether or not it fulfils certain requirements:—

I. It must develop electromotive force suitable for a certain lamp, when driven at a definite speed.

II. It must be self-regulating; that is, the electromotive force generated at the given speed must remain constant to within 5 per cent., whether working one lamp or more, or the full number of, lamps. It is preferable to have a slight fall in electromotive force as the number of lamps is reduced[1] (Fig. 1).

Fig. 1.



The Upper Curve represents the Electromotive Force of a Pilsen Dynamo with Pacinotti Armature as fitted on board S.S. "Thistle," July, 1884.

Speed of dynamo, 440 revolutions per minute. Electro-magnets two wound in series, and two in shunt circuit with armature. Shunt magnets, 64 ohms. Series magnets, 0·31 ohm. Armature, 0·54 ohm. The fall in electromotive force from 20 lamps to 1 lamp is an advantage where an ordinary governor is used, but the fall to the right with from 20 to 40 lamps in circuit is a disadvantage. The lower curve represents the electromotive force of compound wound "Victoria" dynamo D^2 type, suited for 100 lamps of 20-candle power, requiring 60 volts electromotive force. The dynamo was maintained at a constant speed, and shows a remarkably straight curve with a slight rise as the number of lamps is increased.

III. There must be no emission of sparks at the commutator-brushes.

IV. When running light, or with less than the full number of lamps, there must be no undue heating of any of the parts.

V. The conductivity of the copper wire with which it is wound must not be less than 96 per cent. of pure copper.

VI. The insulation-resistance of the armature and electro-magnets should not be less than 10,000 ohms per volt generated at the required speed.[2] The dynamo should be tested mechanically and electrically before it is put on board ship, and afterwards, when fixed in position, by a final trial of not less than six hours' duration, with its own engine, and with all the lamps in circuit, before being passed by the electrical engineer.

There is considerable diversity of opinion regarding the limit of speed of a dynamo on board ship. Amongst practical men (ships' engineers in particular) there is a decided objection to speeds exceeding six hundred to six hundred and fifty revolutions per minute. At higher speeds, one thousand to two thousand revolutions per minute, which are common in installations on land, the bearings need greater attention, there is more noise, more vibration, and, in a pitching, rolling ship, more gyrostatic action and more tangential inertia, tending to burst the armature. Besides these objections, direct driving of the dynamo-armature from the crank-shaft of a fast-speed engine is very popular, and such engines cannot be relied on at speeds of over six hundred revolutions per minute for any lengthened period. As a consequence of this general desire for low speeds, most of the best forms of dynamos, the Siemens (Plate 3, Figs. 7 and 8), the Edison (Plate 2, Fig. 4), the Edison-Hopkinson (Plate 2, Fig. 3), the Victoria (Plate 3, Fig. 6), the Ferranti-Thomson (Plate 2, Fig. 5), and the Pilsen-Schuckert, have been specially modified for ship use, so as to produce the required electromotive force and current, at speeds varying from four hundred to six hundred and fifty revolutions per minute. In order to effect this, their weight and bulk have to be greatly increased, and consequently their weight-efficiency is proportionately reduced.

---

[1] Remarks by Author, p. 24.

[2] This refers to a dynamo for one hundred lamps, p. 89.

SELECTION OF AN ENGINE AND ITS FITTINGS.

The success or failure of an installation on board ship depends as much upon the engine as upon the dynamo, and every care should be taken to procure one that needs the minimum of attention, and is not likely to break down. The engine should be capable of, say, driving the dynamo during a voyage to Australia and back, without a hitch and without requiring overhauling. The demand for such engines, more especially for those driving direct, has led to the production of a great variety, many of them excellent in workmanship and in detail.

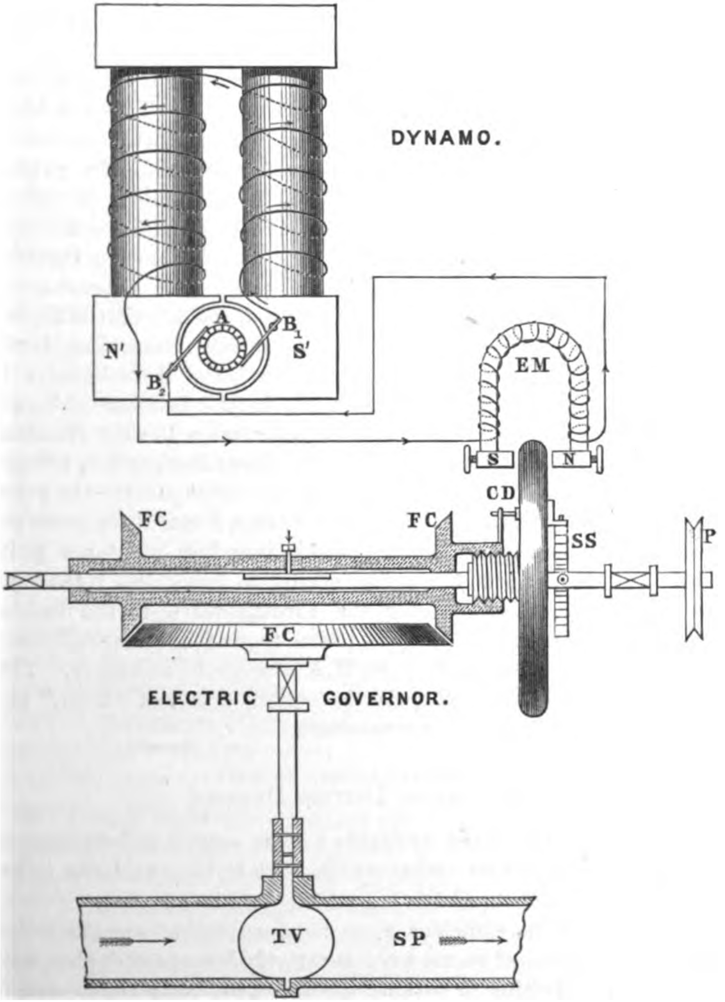
It is frequently necessary that the engine should be capable of doing its work when supplied with steam either from the main- or from the donkey-boilers, so that the electric light may be available in port as well as at sea. This entails a capability for working under variable pressures, and thus the size of the engine must be adapted for the lower pressure. A reducing-valve may with advantage be used when working from the main-boilers, thus wire-drawing the steam down to the normal pressure of the donkey-boiler.

One of the most important adjuncts to the engine is its governor. It should be sufficiently sensitive and reliable in action to keep the engine within 5 per cent. of its normal speed, with a load varying 90 per cent., and a boiler-pressure varying 10 lbs. per square inch. No mechanical governor can do this, and consequently great vigilance has to be exercised on the part of the attendant. A tachometer, or continuous speed-indicator, with a large dial, is usually fitted to or worked from the dynamo-spindle, and a pilot or test lamp is hung between the terminals of the dynamo, or in some easily-seen position, to give warning of any departure from the normal speed and the electromotive force. The Author recently heard of a case in which fifty of the two hundred Swan lamps on board a large passenger-steamer were suddenly broken through a failure of the governor.

A good electrical governor, which shall automatically open and close the throttle-valve, in perfect synchronism with the load, or work to be done, and leave the valve in its last position until a change is made either in the load or in the steam-pressure, is greatly to be desired. The Author, having attempted to solve this problem, may be pardoned for describing his design; because, no matter how perfect the self-regulation of the dynamo may be, that alone will not prevent the breaking of the lamps or undue variation in their light, should the engine be improperly governed or attended to.

The electrical governor (Fig. 2) consists of a copper disk, CD, revolved between the poles of one pair or more of small electro-magnets, EM, actuating a throttle-valve by means of a spring and cones. The wire carrying the current for exciting these electro-magnets is joined in direct circuit with the shunt wires surrounding the dynamo-magnets. If preferred, it may be connected up in series with, or as shunt or compound shunt-series circuit, to the main circuit feeding the lamps, or advantage may be taken of the magnetic poles of the dynamo. There are, therefore, neither contacts nor unsoldered connections to get out of order. The copper disk is loose on the governor-spindle, and is driven, through the intervention of the spiral spring SS, by gearing or by a band passing round one pulley on the dynamo shaft, and another pulley keyed on the governor axle. The centre of the copper disk has a projecting screw on one side, which engages one end of the sliding-sleeve having two friction-cones, FC, FC. Between the friction-cones FC and the throttle-valve TV, a device (not shown) exists for preventing an overturning of the throttle-valve to the right or to the left. When all the lamps, say one hundred, are lighted, and a normal current is passing through the electro-magnets, EM, the copper disk experiences a certain resistance to rotation

FIG. 2.



JAMIESON AND ALLEY'S ELECTRIC GOVERNOR FOR REGULATING THE SPEED OF ENGINES DRIVING DYNAMOS SO AS TO KEEP THE ELECTROMOTIVE FORCE CONSTANT.

N', S', North and south poles of dynamo-magnets. A, Armature of dynamo. B_1 B_2, Brushes of dynamos. E M, Electro-magnet of governor with its wires in direct circuit with those of the dynamo-magnet wires. N, S, Adjustable north and south poles of governor electro-magnet. C D, Copper disk revolving between N, S and connected by—S S, Steel spring to governor-spindle which is driven by—P, Pulley direct from dynamo-axle. F C, Friction-cones or wheels. T V, Throttle valve, working in S P, Steam-pipe.

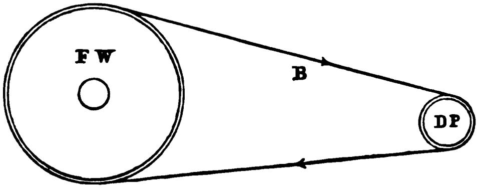
due to the Foucault currents generated in it. This resistance is balanced by the spiral spring; but should any number of the lamps, say ten, be turned out, immediately a stronger current passes through these electro-magnets, and simultaneously with this the speed of rotation of the dynamo, and consequently of the governor, is increased, due to the diminution of the load. This combined increase of current and of speed causes stronger Foucault currents to be generated in the copper disk. It therefore experiences more than the normal resistance to rotation. The effect of this is to coil up the spiral spring SS, thus bringing the left-hand friction-cone into gear with the larger horizontal cone attached to the throttle-valve, and closing the latter about 10 per cent. Whenever the admission of steam has been sufficiently reduced to suit the altered circumstances of the lighter load, the spring, reasserting itself, causes the friction-cones to ungear, leaving the throttle-valve in its last position until a change is made in the number of lamps. Should more lamps be lighted, a reverse action to that described takes place. The normal current in the electro-magnets is reduced simultaneously with a diminution of speed; consequently the poles, NS, are less strongly magnetized, and weaker Foucault currents are generated in the copper disk. There is then less resistance to its rotation; this permits the spiral spring to bring the right-hand cone into gear, thus opening the throttle-valve to the desired amount. When that is done the cones ungear automatically, and the valve is left in position until a change is necessary. This governor is sensitive and quick in action, does not "hunt," and keeps the electromotive force constant.

METHODS OF DRIVING DYNAMOS.

The position and space available for the engine and dynamo on board ship are the first points which have to be considered before determining the mode of driving which shall be adopted.

Should there be sufficient room between decks near the boilers it is more economical to use a comparatively low-speed engine, with fly-wheel and belting or cotton-rope drive, to obtain the necessary speed from an engine making, say, one hundred and fifty revolutions per minute. This plan is often adopted. For example, in the s.s. "Manora," lately built by Messrs. William Denny and Bros., of Dumbarton, for The British India Steam Navigation Co., and fitted by Messrs. King and Brown, of Edinburgh, with Siemens direct-current dynamo for two hundred Swan lamps, a Tangye engine, running at one hundred and sixty revolutions per minute, drives the dynamo at six hundred and fifty revolutions by means of an india-rubber belt direct from the fly-wheel (Fig. 3).

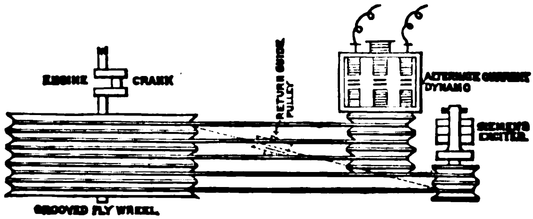
FIG. 3.



F W, Fly-Wheel. B, Belt. D P, Dynamo-Pulley.

In the s.s. "Chicago," fitted with electric light by Messrs. Siemens Bros., an endless cotton-rope is employed, passing from a broad-grooved fly-wheel to the grooved pulleys of Siemens's alternate-current dynamo and direct-current exciter. The return to the fly-wheel for the rope is effected by a cross-connection under a guide pulley fixed to the floor, as shown in Fig. 4.

FIG. 4.



PLAN OF COTTON ROPE DRIVE.

In all such cases the dynamos are fixed upon slides, and can be screwed backwards or forwards so as to adjust the tension of the belt or rope. Where the belt-drive is short, there is also fitted a tightening pulley. This was done in the case of the s.s. "Oregon," fitted by the Edison Co. with Mather and Platt's engines and Edison-Hopkinson dynamos. Such methods of driving dynamos take up a good deal of space. It is often necessary to fit the plant into some small corner of the engine-room, where it is impossible to provide for a belt-drive, and in such cases a direct-driving-engines gearing, or Messrs. Siemens Bros. frictional drive, may be resorted to. Plate 2, Fig. 3, shows the Edison-Hopkinson dynamo driven by a "Tower" spherical engine at five hundred and fifty revolutions per minute, as applied to the steam yacht "Cuhona."

As examples of vessels fitted with direct-driving engines, the s.s. "Pateena" and s.s. "Adelaide," both first-class passenger steamers, despatched from the Clyde for local traffic in Australasian waters, may be instanced, as their electric-light arrangements were carried out by the Edison Co. under the supervision of the Author. By referring to Plate 1, Fig. 1, and Plate 2, Fig. 4, with index of parts, the position of the dynamo and engine in the ship and the details will be understood.

In the s.s. "Pateena" there were one hundred and sixty Edison 16-candle-power lamps, and in the s.s. "Adelaide," one hundred and thirty-one lamps of 16, and four of 100 candle-power, the latter being for facilitating the receiving and discharging of passengers and luggage when in port.

In each case, the Westinghouse engines and the dynamo were bolted to one cast-iron sole-plate placed in a recess near the starting-platform on the ships' floors. Their speed was regulated for five hundred and twenty-five revolutions per minute, which was found sufficient to generate an electromotive force of 90 volts, giving the required 16-candle-power with the lamps as specially provided. Steam was supplied at pleasure either from the main- or the donkey-boilers, at pressures varying from 50 lbs. to 90 lbs. on the square inch, the stop-valve acting as a reducing-valve. Although the best mechanical governors that could be got were fitted, it was found that the speed rose 25 per cent. when 99 per cent. of the lamps were switched out, the remainder being considerably stressed, though not broken during the short space of time that was permitted to intervene before slowing down.

The whole arrangement is exceedingly compact, and has served its purpose admirably in these two ships, the engines only requiring to be looked to every half-hour or so, as they are self-lubricating throughout: in fact, the whole of the lower parts are continually running in oil. The engines are single-acting and the cylinders vertical, so the pressures are always in one direction; pounding is thus avoided, and no adjustment need be made for wear in the bearings. The "Pateena" has been running for more than a year, and the lighting has given entire satisfaction.

Plate 2, Fig. 5, is a side elevation and plan of the Ferranti plant (driven by the Westinghouse engine) supplied by the Hammond Electric Light Co. to Messrs. William Denny and Bros. for the s.s. "Arawa" (Plate 1, Fig. 2) and s.s. "Tainui," which they have just built to the order of the Shaw, Savill and Albion Co. for their New Zealand trade. On each of these vessels a complete double set of Ferranti plant was fitted on one strong cast-iron sole plate.

Provision was made for coupling the plant together while running at full speed, five hundred and fifty revolutions per minute, and thus feeding the whole of the three hundred 20-candle-power lamps with current at an E.M.F. of 100 volts; or each set of plant could be worked independently, and by a combination of switches, either plant could be made to feed any section or set of sections of the ship at pleasure; thus greatly minimizing the chance of failure of the light on board.[1]

Another popular direct-driving steam-motor is Brotherhood's well-known three-cylinder engine, which is shown in Plate 3, Figs. 6 and 7, as applied this year to the electric lighting of H.M.S. "Triumph" and the Brazilian ironclad "Riachuelo." The first adoption of this engine to electric lighting on board ship (arc system) was in 1876, when Messrs. Sautter, Lemonnier and Co. of Paris, fitted up the French ironclad "Richelieu" with a "search light." Since that time the above firm alone have adapted three hundred and fifteen of these engines to electric lighting purposes, of which two hundred and forty-two were for use on board ship, principally for war ships, viz., France one hundred and sixty-one, Italy forty-seven, Austria thirteen, Russia eight, Denmark five, Brazil, Norway, the United States and Turkey eighteen. Altogether, up to date, six hundred and sixteen Brotherhood engines have been applied to driving dynamos.

Considerable improvements have been made in this engine since it was first introduced, the latest being piston-valves, thus doing away with the long steam-passages and the leakage through the former kind of disk-valve, and a flexible coupling (Fig. 5) whereby the stress due to wear of the dynamo spindle-bearings, and any untruth in the line of the same with that of the engine shaft, are reduced.

The largest engine of this type that has been applied to dynamo driving is one indicating 42 HP., running at six hundred and ten revolutions per minute, and consuming about 4 lbs. of coal per indicated HP. per hour.

Mr. A. C. Kirk, M. Inst. C.E., the managing partner of Messrs. Robert Napier and Sons, has applied internal cast-iron gearing, in the case of three large Mexican mail steamers which his firm has lately built, to getting up the necessary speed between the engine and dynamo. The arrangement is strong and compact, there is no chance of slipping, and the noise is tolerably well overcome by encasing the gearing in a wooden muffling-box. The whole plant is placed in a recess in the engine-room on the ship's floors, where it can be attended to by the men on watch at the main engines.

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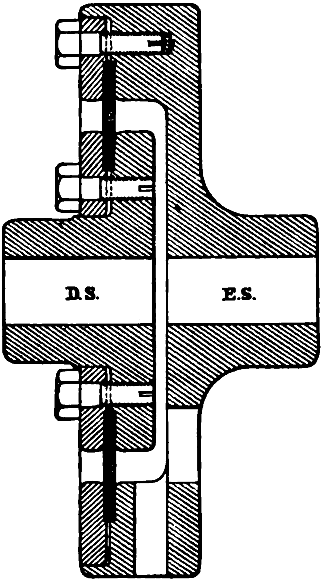
[1] Remarks by Author, p. 24.

FIG. 5.



E S, Engine Shaft. D S, Dynamo Spindle. L, Leather Disk.

Messrs. Siemens Bros. have lately brought out a compact form of rolling contact or friction drive (Plate 3, Fig. 8), thus enabling an ordinary vertical engine to work their direct-current compound shunt-wound dynamo at any desired speed. The dynamo-pulley F P, which is covered with papier-mache, is caused to bear evenly on the engine fly-wheel F W, by means of two adjusting rods A R. The dynamo is supported in a cradle on cross-bearings or trunnions, which relieve the armature and its spindle from any stress except that due to the torque necessary to revolve it. This arrangement has given great satisfaction wherever it has been introduced, the only special precaution being to keep the paper-pulley dry and free from oil.[1]

SYSTEM OF LEADING WIRES AND THEIR SIZES.

There are two systems upon which leading wires may be fitted on board ship, the one with forward and return, main and branch leads, or what may be termed the double-wire system, as in Fig. 6:—Plate 1, Fig. 1, plan of s.s. "Adelaide," is an example of a ship wired on this system.

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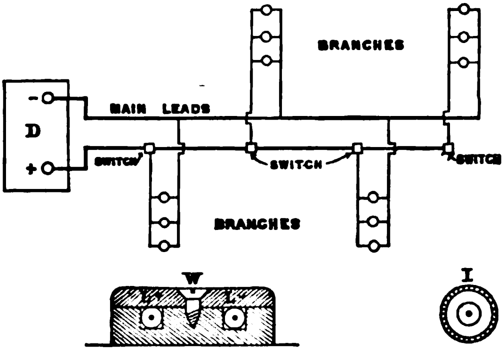
[1] Remarks by Author previous to discussion, p. 24.

FIG. 6.

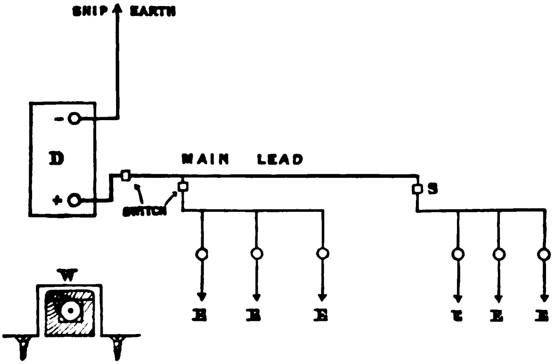

BRANCHES
MAIN LEADS
D
-
+
SWITCH
SWITCH
SWITCH
BRANCHES
W
L+
L-
I

DOUBLE WIRE SYSTEM.

D, Dynamo. W, Wooden Casing (cross-section) for carrying and preserving leads (L +, L −) I, Metal Pipe (cross-section) for carrying leads in boiler-rooms. The circles represent lamps.

The other system uses the iron plating and beams of the ship as a return for the electric current, and so may be called the single-wire system, as in Fig. 7.

FIG. 7.


SHIP
EARTH
-
D
+
MAIN LEAD
SWITCH
S
E
E
E
E
E
E
W

SINGLE WIRE SYSTEM.

D, Dynamo. W, Wooden Casing for carrying and preserving leads. E, Earth-connections. S, Switches. The circles represent lamps.

The advantages of the latter system are these: it is less costly, more easily fitted, and offers about one-half the resistance to the current, as only about one-half the length of wire required for the first system suffices. The disadvantages are, that a fault in the insulator or dielectric of the leading wire has a more direct effect upon it than upon the double-wire system, for any accidental connection of the conductor with the iron of the ship at any point, short-circuits the wire at that point. It is also found that if, through the ship leaking, salt water should penetrate the dielectric to the conductor, the latter will soon be eaten through by galvanic action, sub-chloride of copper and soda being formed. Faults of this description have occurred with both systems and given considerable trouble, but with first-class dielectrics, good joints, and by carefully encasing the leads in varnished or paraffined grooved wooden casings, such accidents should not happen, as the conductor would then be protected by a waterproof casing throughout except at the switches and lamps. Plate 1, Fig. 2, plans of s.s. "Arawa" and s.s. "Tainui," are examples of ships wired on this system, but extra care and the very best insulated leading wires have been used throughout, as verified by the Author's tests.[1]

All joints in the leads should be carefully made by experienced workmen. They do not require to be so well done as in submarine telegraphy, as they have not to withstand the water-pressure, and the requisite insulation-resistance is not so high; nevertheless the metallic junctions should be thoroughly well soldered, the dielectric ends cut down to a taper with a sharp knife, and thereafter the whole covered with wrappings of felt, pure rubber, and waterproof tape, being finally varnished.[2]

It is most important that the size of the conductor should be sufficient to carry the necessary current without causing more than 2 to 3 per cent. loss of the electrical power developed in heating them. Sir William Thomson's law for bare conductors, viz., not less than 1 square-centimetre for 50 amperes, which is based on the principle that the total loss is a minimum when the two component losses are equal, *i.e.*, when the annual cost of power wasted in heating the conductor is equal to the yearly interest plus depreciation on its value, is too liberal an allowance of copper in the case of well-insulated short leads; besides which he has omitted to add the insurance on the value of the wire which, in the case of ships' fittings, amounts often to 7 per cent. The Author has used a rule which he finds to work well in practice for ships' leads where the length is never great, viz.:—

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[1] Reply to discussion, p. 90.

[2] Detailed rules for making joints in electric light leads. "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," p. 230. Third edition. Also remarks by Author previous to discussion.

"The conductor to be of best copper of not less than 95 per cent. of the conductivity of pure copper, and to have a cross section of 1 square millimetre for every ampere and a half of current passing through it (which is at the rate of about 1,000 amperes to the square inch); the insulation-resistance of the whole circuit when fitted including all switches, &c., to be not less than 1,000 ohms per volt of electromotive force generated by the dynamo."

Before fitting the wires, specimens of not less than 100 feet should be selected, immersed in sea-water, or brine-water for twenty-four hours, and then carefully tested for insulation-resistance, and not passed unless they give over 10 megohms. Specimen joints should be treated in the same way and give at least 100 megohms each.

Although the above rule for the size of conductors is considerably in excess of that required by theory for mere safety from heating, and not applicable to large and long district mains, it has been found in practice to give excellent results in small installations on board ship and in houses, where the maximum current conveyed by any leading wire does not exceed 300 amperes, and the farthest lamp is not more than 100 yards from the generator. The required sizes of the conductor are easily calculated or found direct from the Tables[1]; those for even single lamps are of sufficient size and strength for rough handling. There is not the slightest danger from heating in any part of the circuit, and the rule is economical when applied to the best class of insulated leads. Based upon this rule, in the following Table (p. 16) will be found the most common sizes of leading wires used in ship installations, and which the Author is in the habit of handing to contractors working to his specifications.[2]

It is seldom that on board ship more than 300 amperes are generated by any single dynamo; and, as several main leads usually spring from the dynamo-room to various parts of the ship, the current in any one of them seldom exceeds 100 amperes, so the wires do not vary greatly in size, and generally four sizes will suffice for a ship.

Insulation-resistance is too often neglected by electric-light engineers. Amongst submarine-telegraph engineers it is con-

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[1] "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," pp. 178, 217-222, 223-226. Third edition.

[2] Reply to discussion, p. 89.

TABLE for SIZES of SHIP LEADS (WELL INSULATED).

For Swan 20-*Candle-Power or Edison* 16-*Candle-Power Lamps.*

Maximum Number of Lamps to be carried.	For 45 to 60 Volt Lamps Requiring 1·5 to 1·1 Amperes.	For 90 to 110 Volt Lamps requiring 0·8 to 0·6 Amperes.
	Board of Trade Wire-Gauge; Branch Leads.	Board of Trade Wire-Gauge; Branch Leads.
1	No. 18 wire	No. 20 wire
2	„ 16 „	„ 18 „
3	„ 15 „	„ 16 „
10	„ 10 „	„ 12 „
	Main Leads' Strand.	Main Leads' Strand.
20	7 No. 15^{s}.	7 No. 16^{s}.
25	9 „ 15^{s}.	7 „ 16^{s}.
45	19 „ 16^{s}.	7 „ 14^{s}.
60 to 70	19 „ 14^{s}.	19 „ 16^{s}.

sidered of vital importance to watch the insulation-resistance with the most rigid accuracy, not only during the manufacture of a cable, but during its submersion and after it has been laid; whereas in the case of electric lighting, those charged with the fitting up of an installation very seldom think of, or even know how to take, insulation-tests, either of the dynamo or of the leading wires. The Author has found great difficulty, in most installations with which he has been connected, to get the contractor to recognize the importance of this test; in fact he has only met with one instance in which the contractor himself used testing-apparatus which would detect a small flaw in the insulation of the wires after they had been fitted. To this general neglect of testing conductor- and insulation-resistance may be attributed some of the failures that have occurred.

It is far from right to allow leads to be run up like bell-wires, without the slightest knowledge as to whether a flaw or a fault has crept in, and all engineers should insist upon rigid inspection, as well as thorough and searching tests, before an installation is passed. The insulation-resistance-standard need not be nearly so high as in the case of submarine cables; but nevertheless it does require to be several hundred times more than the copper-resistance, otherwise a fault will soon develop, and short-circuiting occur, under the combined influences of the electromotive force and damp or wet.

The dielectric should, therefore, in addition to being a good insulator, be thoroughly watertight, and as little liable as possible to be affected by atmospheric changes.

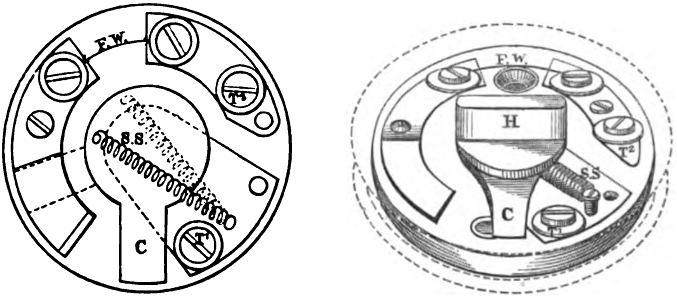
SWITCHES AND FUSIBLE JUNCTIONS.

There are three methods of arranging the main switches on board ships, the first by having all situated in the dynamo room, whereby the circuits are wholly controlled by the man attending to the engine and dynamo. The second, by having one main switch to control the whole current, near the dynamo, with the others situated where the different main circuits branch off, so that they can be turned off or on by the ship's servants as required. The third method is to have main switches, not only in the dynamo room, but also at the base of the different departments. The last plan introduces unnecessary complication, and the first can only be carried out when all the different circuits spring direct from the dynamo room. The second is more general, and serves all requirements now that self-regulating dynamos have been introduced, and if care be taken that too many of the circuits are not put in or cut out at one time, so as to overtax the powers of the engine-governor. In most installations each lamp is fitted with a switch, so that every passenger may turn on or off his light at pleasure, which is no doubt convenient for the passenger; and after the novelty has passed away there need be little fear, in a well-regulated ship, that the privilege thus afforded will be unduly taken advantage of, or the switches or lights tampered with. One of the best and simplest forms of these small switches, introduced into this country by Mr. H. C. Harold, is shown in Fig. 8. The merit of this switch is that it remains hard on or hard off as the spiral springs S S act on each side of the dead point. The contacts are scraping contacts and can be easily cleaned. Fig. 9 shows the Hammond Co.'s switch for the same purpose.

An excellent form of main switch, as fitted by Messrs. William Denny and Bros. into the Shaw-Savill steamers, is shown in Fig. 10, where double-spring scraping-contacts are provided on each side, and the lower contact projects beyond the upper one, so that any accumulation of dirt due to "sparking" on opening or breaking circuit may be readily removed by cleaning it with emery-cloth.

Fusible or safety wires should be introduced into all the main and branch circuits. The size for the branch circuits being such that they will give way before the current becomes dangerously

FIG. 8.

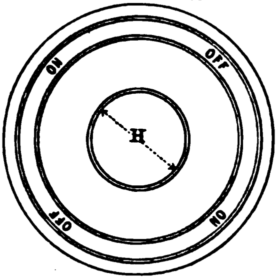


THE LUNDBERG IMPROVED ELECTRIC LIGHT SWITCH.

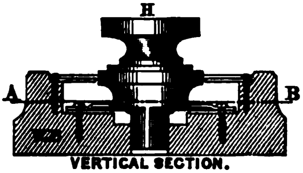
C, Contact Tongue, which may be turned to right for contact and to left for free by handle H. S S, Spiral Spring, which keeps C hard on or hard off. T^1 T^2, Terminals to which the leading wires are attached. F W, Fusible Wire, generally composed of tin or of composition metal.

FIG. 9.

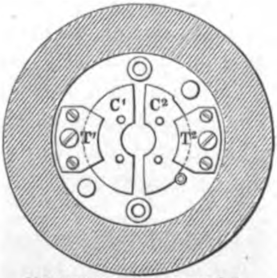
HALF FULL SIZE.



OUTSIDE PLAN.



VERTICAL SECTION.



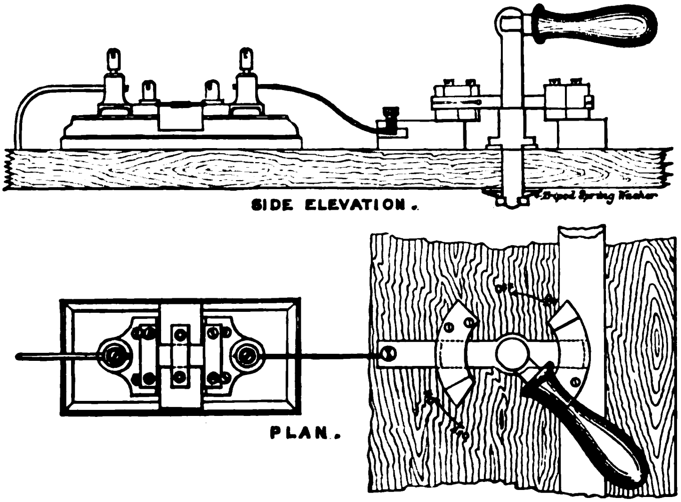
SECTION PLAN THROUGH A.B.

THE HAMMOND ELECTRIC LIGHT CO.'S SWITCH FOR BRANCH CIRCUITS.

H, Handle. C^1 C^2, Contact Plates. W B, Wooden Base.

strong for the smallest leading wires of the section. In most instances the small safety "cut-outs," which some firms introduced in circuit with each lamp, did not act so as to save the lamps from destruction. To guard an Edison or Swan lamp, requiring 1 ampere or less, from breaking through excess of current, the fusible wire, to be of real use, would have to be so very fine as to be difficult, from a mechanical point of view, to handle or replace. A neat method of overcoming this mechanical difficulty has, however, been fitted into the s.s. "Manora." A thin narrow strip of tinfoil in the form of a double hook or S, is pasted on a piece of insulite, to stiffen and support it, each end of the S being fixed down by means of a screw, whereby the current feeding the lamp has to pass through the tinfoil. Its dimensions are such that it will fuse with about twice the normal current required for the lamp.

Fig. 10.



Main Switch Arrangement, s.s. "Arawa," with Hedges' Fusible Bridge.

Scale ¼.

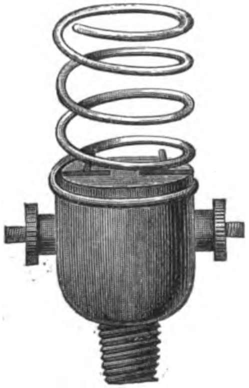
All fusible wires or "cut-outs" should be so fitted that they can be readily inspected and replaced by fresh ones when required. They should be as short as practicable, so as to increase the resistance of the circuit as little as possible.

Lamp-holders, Lanterns, and Globes.

In choosing the kind or form of lamp to be used, there is so little difference between the efficiency and lasting powers of those of the different makers, that the chief things to be attended to are, that they should be of the required candle-power when supplied with the current and electromotive force of the selected dynamo.

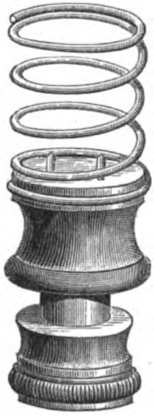
Lamps of 10-candle power are sufficient for most cabins, of 20-candle power for saloons, music-rooms, smoke-rooms, boiler- and engine-rooms, and of 50- or 100-candle power lamps, for side-lights, masthead-lights, gangways, and hatchways, or a cluster of 20-candle power lamps.

Fig. 11.



For Double Wire Circuit.

Fig. 12.



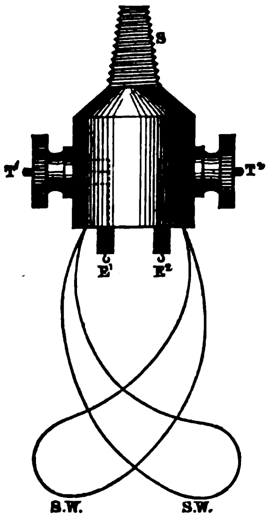
For Single Wire Circuit.

Messrs. Siemens' Terminals for Swan Lamps.

It is important that the holders for the lamps should enable good, easy, but firm contacts to be made between the terminals of the lamp and the leads, and that the vibration of the ship should not work the contacts loose or permit of the filament being unduly shaken, which action is found considerably to reduce the life of the lamps (Figs. 11, 12, and 13).

Lanterns, and globes have been designed, not only for use on land, but also for ship purposes, and in this respect the electrician has been ably assisted by those who make it their business to provide these appliances. Such appurtenances should be both elegant and durable, and be fixed so that the light is shed downwards on the passenger, rather than hung on a level with his eyes, the most approved plan of lighting being to suspend short brackets with their globes from the ceiling over the centre of the tables, so that they are clear of the passage-ways and wine-glass holders, and distributed so as to give a uniform light, as in Messrs. Siemens Bros. fittings, which have given great satisfaction. The original plan of fixing the electric-lamps inside or attached to the oil-lamps is in great measure discontinued, as an unnecessary complication. In some steamers, where the cabins enter off the saloon, devices such as lanterns of triangular section have been resorted to. By this means the cabins and the saloon are simultaneously lighted, but in this respect each particular shipbuilder or owner has more to say than the electrical engineer. In the engine-room, lanterns with reflectors and wire-cage protectors are largely used, as well as lamps attached by flexible leading wires, to permit of the engineer inspecting different parts of the machinery. In the boiler-rooms the lamps are so fixed as to cast their light directly upon the water-gauge glasses, that the height of the water in the boilers may be readily and easily observed from the stokehole floor.

FIG. 13.



HAROLD'S GLOW-LAMP HOLDER.

S, Wood or Ebonite Screw. T^1 T^2, Brass Terminals. E^1 E^2, Electrodes to attach to the lamp platinum hooks. S W, Spring Wire for keeping the glow-lamp tight and yet easy in position.

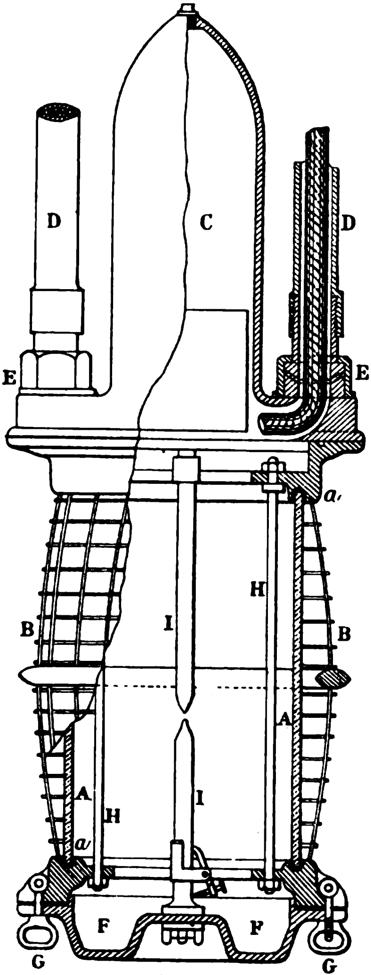
Arc Lamps on Board Ship.

Arc lamps are seldom used on board passenger-steamers, but they have been found of great use in telegraph steamers, in facilitating paying out, picking up, and repairing operations when conducted at night, and in spotting "mark buoys."

They are largely used in foreign navies, as well as on board British men-of-war. In such cases the arc light is placed inside a revolving holophote case (fixed upon the bridge or well forward), and fitted with a lens and reflector, so as to throw a concentrated beam of light in any desired direction, with the view of inspecting an enemy's position, or of guarding against the attack of torpedo-boats. Such lights are worked from a separate dynamo, and require to be at least 10,000- to 20,000-candle-power. They have been applied successfully by Messrs. Siemens Bros., the Silvertown Company, and by the Anglo-American Brush Company to English men-of-war.

A novel application of the arc light for salvage- and fish-ing-purposes has been fitted by Messrs. Paterson and Cooper to the s.s. "Tilly," for fishing in Batavian waters. The installation consists of a Gwynne vertical engine, supplied with steam from the ship's main boilers, a Phœnix

Fig. 14.



Scale ⅛.

A, Glass Cylinder enclosing arc lamp 15,000-candle power, made water-tight by indiarubber rings *aa*. **B**, Copper Wire Cage protecting glass cylinder. **C**, Dome enclosing mechanism of lamp. **D**, Copper Conductors from dynamos, enclosed in indiarubber tubing. **E**, Hydraulic Joints at the ends of conductors. **F**, Removable Door of lamp for adjustment of carbons. **G**, Wing-Nuts for ditto. **H**, Rods connecting top and bottom portions of lamp. **I**, Carbons 20 millimetres in diameter.

dynamo, and the submarine lamp of 15,000-candle-power. It is represented in Fig. 14 as fitted with paying-out gear and well-insulated leading wires to reach any required depth. This is the only instance known to the Author of the adaptation of the electric-arc light to submarine purposes, but if the idea is practicable and successful there is ample scope for its application.

Electric-lighting installations on board ship, as well as on land, should be thoroughly well carried out in every particular. Many of the disappointments, failures, and accidents which have occurred have been caused by want of knowledge or carelessness, either on the part of those ordering plant or of those executing orders. The Author recalls to memory Mr. Preece's well-timed caution, in his Paper "On Electrical Conductors," where he says:—"It cannot be too strongly urged that specification without rigid inspection is valueless. . . . Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect."[1]

The Paper is accompanied by numerous illustrations, from which Plates 1, 2, and 3, and the Figs. in the text have been prepared.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxv., p. 74.

Discussion.

Sir J. W. Bazalgette. Sir J. W. BAZALGETTE, C.B., President, said that the Paper was well worthy of the consideration of the members at the first meeting of their session. It was one of a practical character, on a comparatively novel subject, of great interest, and he was quite sure that the members would desire to give their best thanks to Mr. Jamieson for the careful manner in which he had prepared it, and for the trouble he had taken in travelling from Glasgow to London to be present at the meeting.

Mr. Jamieson. Mr. A. JAMIESON desired, before the discussion commenced, to draw the attention of members to the electromotive-force curve of the "Victoria" compound-wound dynamo (Fig. 1). That curve represented the electromotive force of the dynamo when generating currents from 0 to 120 amperes. It was very nearly a horizontal line throughout, and was a remarkable illustration of the rapid improvement that had been made in dynamo machinery within the last two years. How much of this constancy of electromotive force (with varying resistances in circuit) was due to the weight and arrangement of iron in the armature and magnet cores, and how much to the proper proportioning of the size and number of turns of wire in the shunt magnet circuit, to that of the main (or direct) circuit in the armature and magnets?

He wished to mention an experiment tried in connection with the s.s. "Arawa." There were two complete sets of plant, all in line on one sole-plate (Plate 2, Fig. 5, showed one set), either of which was capable of working more than one-half the number of lamps in the ship, the total number being three hundred. When only one hundred and fifty lights or less were required, one set of Ferranti plant was kept in action, but when more than one hundred and fifty or one hundred and sixty were necessary, the second engine was brought up to the same speed as the other, and the two were put into gear. Advantage had therefore to a certain extent been taken of the suggestions given by Dr. Hopkinson in his lecture on "Some points in Electric Lighting," delivered before this Institution, viz., "that two alternate current machines could be used for feeding one set of lamps when the forward and return circuits were common to both machines.

In the case of Siemens' frictional drive, the engine drove, through the intervention of a fly-wheel, and a compressed paper pulley, a dynamo at fifteen hundred revolutions per minute. This arrange-

Mr. Jamieson.

ment got over the objection of the conservative marine engineer; for he need not see the dynamo revolving at that rate; as the whole apparatus was put into a small corner, and partially covered, so that he was thoroughly satisfied. It had given excellent results wherever adopted.

The rule which he had applied to the size of conductors for electric-lighting in steamships was not a mere arbitrary rule; it was the application of Sir William Thomson's to the particular case of short insulated wires. Mr. T. H. Blakesley, Assoc. M. Inst. C.E., had worked out this question in a Paper read before the Society of Telegraph Engineers.[1] The Author had worked out the same thing some time before in a similar manner for a particular class of leads, and their results agreed very closely. Seeing that not more than 100 amperes were required in any single main lead on board a ship, the sizes of the wires by which a ship could be fitted were few; so that, by means of a rule like that which he had mentioned, a contractor, with the table before him, could at once fit a ship without any trouble in computing formulas.

He had left the question of first cost and maintenance of the electric plant to those who knew more about it than himself, and he hoped that some practical results would be given in the discussion with regard to the length of life of the Swan lamps, the price of installations under different circumstances, and their saving as compared with oil or candles.

Dr. Hopkinson.

Dr. JOHN HOPKINSON said that the reason of the success in the compounding of the Victoria dynamo, and some others with which he was acquainted, was that the amount to be corrected by the series coils was small; that was attained by the fact that the field in which the armature revolved was exceedingly intense, and that the resistance of the armature was low. The error to be corrected being small, it could be reduced by the correction to an exceedingly small amount. In machines where the resistance was not so small, and a considerable amount of correction was required, it was not possible to obtain such a degree of accuracy. There was another point with reference to the use of compound dynamos. There could, he thought, be no question that in cases where a single dynamo was connected to the circuit, there was a very great advantage in using a self-regulating compound dynamo. If, however, two compound dynamos were connected to the same circuit, there was an instability in the division of the work between the

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[1] "Journal of the Society of Telegraph Engineers and Electricians," 1884. Vol. xiii., p. 295.

Dr. Hopkinson. two machines, so that one would be overloaded and the other do nothing. The remedy for that was easy. If there were two machines, instead of each machine correcting its own error by its current passing round its own magnets, the current from each machine was taken round and used for exciting the other. The plan, he believed, was an old one, and had first been adopted in the ordinary series machine, some years ago, in experiments made at the South Foreland; but it was worth recalling now, when compound dynamos were in frequent use, and were likely to be connected together with the same circuits. The Author had given what might be called a specification of what he considered the necessary insulation-resistance of dynamos. Dr. Hopkinson thought that such a hard and fast line was not desirable. The smaller the machine the higher should its insulation be. If the size of the machines were doubled, it might fairly be expected that its insulation-resistance—the surfaces being doubled or thereabouts—need not be more than a half, with an equal degree of efficiency and safety. With regard to the size of conductors, there were several points to be taken into consideration. One point was, that the conductor should be such that with its ordinary current it should not get excessively heated. Another was, that the distribution of the potential through the system should be constant; that it should not vary so as to endanger the lamps where it was high, or give an inefficient light where it was low. The third was that energy should not be wasted, and on the other hand, that too great outlay should not be incurred in the first instance in copper. Practically the last was really the consideration which in most cases should regulate the size of conductors. He thought that, in a very large number of cases, conductors were put in smaller than they ought to be, from mere motives of economy. He was sorry that the Author did not go so far as Sir William Thomson's rule. He wished that everybody would go as far as that. It was very difficult to take the exceptional course of insisting on a little more expenditure in prime cost, when everybody was cutting down the cost too fine. Then, with regard to the size of conductors, it was possible that accidental connections might be made between the two conductors which took the electricity to the lamps, and took it away from them, and in that case an excessive current might pass through the conductors. To provide against that, cut-outs, as they were called, had been introduced which, if the current was excessive, would be fused before the wires became too hot. If the conductors were reduced at every branch to their minimum fair limit for the current which they had to carry, then at each branch cut-outs should

Dr. Hopkinson.

be introduced. That involved a certain complication. Sometimes economy would be realized by making the smaller conductors of a larger size, and consequently avoiding the necessity of so many cut-outs. A sufficiently large conductor could be put to a single lamp to carry considerably more than the current for one lamp, enabling the electrician to dispense with a cut-out for each lamp, and to put one in for groups of three or four. That was more a question of cost and convenience than anything else, but he thought that economy would be realized by increasing the size of the smaller conductors, and diminishing the number of cut-outs. Another point referred to by the Author was the relative advantages of two methods of wiring a ship; first, that of having a conductor to take the electricity to the lamps, and an insulated conductor to take the current back from the lamps; and secondly, that of having a single set of insulating conductors using the ship itself as a return. For his own part, he greatly preferred the former method, for this reason: it was not merely a question of having, so to speak, two strings to one's bow in the insulation; it was not merely that if there was a breach of insulation there was likely to be a breach between the copper and ironwork of the ship; but it went further; if such an accident occurred—if the earth insulation of one of the conductors broke down, and there was consequently a contact between the conductor and the body of the ship—if both systems were insulated, the electricians would, by proper arrangements, be aware of the fact that the insulation had given way before any danger or inconvenience occurred, and steps could be taken to remedy the defect. Besides, if there were two systems of conductors, both insulated, it was easy, when the machine was in operation, without interfering with the work in any way, to determine the insulation-resistance of both the positive and negative conductors. It was a great advantage to have it determined from time to time, so that if any defect was beginning to be developed steps might be taken to remedy it before any mischief could arise. For those reasons he felt strongly that, though good work might make a single-conductor system thoroughly satisfactory, still the least defect might always lead to serious damage without giving any warning; whereas in the other case, if the work were not so good, whenever a defect occurred notice was given of it before any mischief arose. With a little watching and attention the whole might be made perfectly secure. As to the use of alternate currents, when he had the honour of lecturing before the Institution, he pointed out that alternate-current machines, even if they were independently driven, had the power of regulating each other;

Dr. Hopkinson. that if they were coupled in parallel circuit they would tend to add their effects, and if in series they would tend to neutralize each other. Since then that point and other points connected with it had been experimentally verified, so that there could be no question about it. The synchronism of two alternate-current machines, when connected together, had been described by Mr. H. Wilde sixteen years ago;[1] but this Paper had been unfortunately overlooked by those interested in the subject. The Author, he thought, did not completely apply that theory to the particular case shown in Fig. 9. There was no need whatever for any clutching of the two machines. The machines themselves, when once started at the same speed, even though driven by independent straps, would control each other and drop into perfect synchronism, marching in step, even though each was making three hundred steps in a second, and with a power of 20 or more HP. The effect of the control in that case would actually be to produce what the Author had shown.

Professor Perry. Professor JOHN PERRY said that the Paper was a very useful one, and he only regretted that it did not contain a little more of the Author's own statistics. In speaking of compound dynamo machines, neither the Author nor Dr. Hopkinson had referred to the name of Mr. Marcel Deprez who really originated the principle of compound winding, and made it possible for a dynamo machine, kept running from a well governed engine at a constant speed, to develop almost exactly the same electromotive force, or to give the same light from every lamp, whether one hundred lamps were burning or only one of a circuit. True, Deprez regulated his dynamo in a different way from the latest compound-winding method, as it was also different from the method of himself and Professor Ayrton; but the methods were all essentially the same in principle, and he regarded the discovery of this principle by Deprez as the greatest discovery since that of the dynamo machine. One of the most important points in the Paper was that relating to the positions of the dynamo and of the engine in the ship. It was possible that mechanical engineers had not got sufficiently accustomed to the idea of gyrostatic action to take account of the pressures on the bearings of rapidly spinning bodies such as dynamo machines. He supposed that it was natural for electrical engineers to consider gyrostatic actions. They were accustomed to think of a magnet as a ship with a great number

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[1] Proceedings of The Literary and Philosophical Society of Manchester, vol. viii., p. 62; and Philosophical Magazine, Fourth Series, vol. xxxvii., p. 54.

Professor Perry.

of compartments, there being in each compartment a rapidly spinning body. Sir William Thomson first drew attention to this matter, and it was very natural for him to do so as he first explained why a top rose, why a stone rose on its longer axis when spun, or why an unboiled or rotten egg would not get up on the table when an attempt was made to spin it, whereas a well-boiled egg would get up. Anyone who had held one of Sir W. Thomson's large gyrostats in his hands, and had tried to turn it, knew that considerable pressure might be produced at the bearings of dynamo-machine armatures. When the dynamo machine was turned about an axis, the armature tried to place its axis of spinning parallel to the axis of turning. Now, from what had been said, some members of the Institution might have come to think that quick-speed engines were a disadvantage in ships. As he rather advocated the use of quick-speed engines for the driving of dynamo machines and other purposes, he and Professor Ayrton had examined the question of the relative pressures on the bearings of, say, the crank-shafts of two engines of the same power, one a quick-speed and the other a slow-speed engine, and they had found that, taking the same ratio between the initial pressure of steam and the mean pressure of steam in the cylinder, to give the same fluctuation in speed, the moment of inertia of the fly-wheel was inversely proportional to the cube of the speed, and therefore the gyrostatic couple, the couple which produced the pressure on the bearings due to any rotation of the ship, was inversely proportional to the square of the speed. The dimensions of fly-wheels which were made to the same drawings but to different scales, were inversely proportional to the fifth power of the moment of inertia, and the result was an inverse proportionality to three-fifths of the power of the speed. Hence the pressure on the bearings of the engines was inversely proportional to one and two-fifths of the power of the speed. Taking into account the fact that in quick-speed engines there was a longer bearing, it might be said roughly that the pressure per square inch on a bearing was inversely proportional to a small power of the speed, which was favourable to a quick-speed engine. But suppose the subject to be looked at from the ordinary point of view of the mechanical engineer. In the first example taken by the Author, of a Siemens armature, the pressure on the bearings was found to be 3·6 lbs. If it were supposed that this dynamo machine was placed in the ship in such a position that it could get an ordinary translational motion of 10 feet amplitude, and taking the sixteen seconds periodicity of swing, it was found that the pressure on each bearing would be 12 lbs.; so that the pressure

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due to the cause generally considered by the engineer was three and a half times as great as the pressure due to the gyrostatic action. Further, he had considered the case of a ship having a swing, which was a simple harmonic motion, and it was well known that occasionally towards the end of a swing there was something very different indeed from the end part of a simple harmonic motion. So the pressure on the bearings might be many times greater than the gyrostatic pressure which had been spoken of. It should be remembered that the gyrostatic action was proportional to the greatest angular velocity of the ship, whereas the second action of which he had spoken, the one well known to engineers, was proportional to the rate at which the motion was altered. With regard to governing, the Author had spoken of 10 per cent. fluctuation in speed as not attainable, and he had stated as an example, that when one hundred lamps were being burned, and ninety-nine lamps were suddenly switched out, and only one lamp was left in, the difference in the speed for an instant was about 25 per cent. No one would be astonished at that. If 99 per cent. of the whole work was suddenly taken off the engine, it would be a most extraordinary stoppage of power, and probably in practice nothing like that sort of stoppage of light could ever occur except as a total stoppage. In any case, he had no doubt that if an electrical engineer would only ask a mechanical engineer for a minimum fluctuation of 10 per cent. in speed when there was, say, 80 per cent. fluctuation of power, he would get it. It was because they had not been in the habit of asking for good governors that electrical engineers had not obtained them hitherto. The electrical governors, sometimes spoken of as very good, appeared to him to be only comparatively good. They all depended on the principle that if there was an electro-magnet, and a certain current passing round that magnet, the magnetic field produced by the magnet was constant. Now it might be advisable to warn inventors that the magnetic properties of iron were hardly known to the writers of books and to electricians who had not made them a special study; and that measuring instruments which seemed excellent hypothetically were often practically very bad. And in regard to the action of strong electro-magnets differing in character from the weak ones used in Ayrton and Perry's Solenoid Ammeter and Voltmeter, they might use the very best of the three best brands of Swedish iron, they might anneal it in a vacuum from such a high temperature as to make them afraid that the shape of the iron would be spoiled, they might take care that no file or other tool touched it afterwards, and if they tested it in a strong electro-

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magnet they would find that the field produced was not always the same for the same current. Let them for example increase the current from 0 to 20 amperes, and then see what the field was. Now beginning with 30 amperes, and coming down to 20, it would be found that the field was not the same. The character of the field depended to some extent on the past history; he wished it did not. That was a defect which would be found in all electric governors of engines, depending upon the action of a strong electro-magnet. As to another matter, the size of the leads, Sir William Thomson's rule led to a little over 3 square inches of copper in the lead per 1,000 amperes of current. Taking, however, the copper at £100 instead of £75 per ton, and 15 per cent. for interest and depreciation, the result was 2 square inches per 1,000 amperes. Mr. Blakesley took 1 square inch for 1,000 amperes, allowing for the cost of the insulation of the leads; but it seemed to Professor Perry that too much stress was laid upon the cost of the leads. Because Sir William Thomson, at the time when transmission of power for long distances was engaging attention, just after he had been discussing the transmission of power from Niagara to New York, based his calculations on what was then all-important, the cost of the copper leads, every electrical engineer now based his calculations on the cost of leads, although they might only be a few feet in length. The much more important consideration for single house and ship lighting was neglected, namely, ought not the light from the lamp to be constant? Given the best governor imaginable, whether electric or whether a mechanical governor, the dynamo machine being double wound, it only aimed at keeping the difference of potential constant at some one place in the system, so that a lamp at that place would be always of exactly the same brightness. But it did not follow that at a certain other place the light would always be of the same brightness. It depended on the number of lights between one place and another, and on the section of the leads. If a number of lights were switched out, there would be a different brightness in a particular lamp from its brightness before the others were switched out. Thus if there were absolutely perfect governing in the dynamo room in the Author's system, and if a room contained, say, fifty lights, fed by cables 200 yards in length from the dynamo room, and if forty-nine were switched out, the remaining lamp must have its potential increased 2·46 volts. Now an alteration of even a fraction of a volt was annoying in a 100-volt lamp, so that an alteration of 2·46 volts was a very

Professor Perry. important matter. The only way in which this could be prevented was by lavishness in the cost of the copper cable, and this part of the total cost of a ship-lighting installation was comparatively small.

Sir J. W. Bazalgette. Sir J. W. Bazalgette, C.B., President, said that the Author thought the discussion upon his Paper might well embrace observations on the following points:—1. Direct-driving engines *versus* other methods. 2. Governors, electric and mechanical. 3. Low- *versus* high-speed dynamos on board ship, with their relative efficiencies, curves, weights, and cost. 4. Alternate- *versus* direct-current dynamos. 5. The two systems of fitting leading-wires on board ship. 6. The sizes of wires and their necessary insulation-resistance. 7. Fusible cut-outs and lamp-fittings. 8. The first cost, life, and maintenance of the different kinds of plants, or of the dynamo machines tried on board ships. 9. Search-lights; their uses, first cost, and maintenance.

Mr. Preece. Mr. W. H. Preece said he was not aware that it was customary for the Author of a Paper to lay down points to which the discussion should be directed; it was rather for those who had heard or read the Paper to form their own opinion as to what should be taken up for discussion. There were, he thought, two satisfactory points in the Paper, to which attention should be paid; the first was, that there was at any rate one branch of electric lighting that had turned out to be an unqualified success. The Author, and those who had introduced electric lighting on board ship, had certainly brought to the traveller a comfort that none but those who had been down to the sea in ships could thoroughly comprehend. It had been his lot to have recently experienced the great discomfort of a journey across the Atlantic. He had travelled in the rear of a severe cyclone, and for two days the ship tumbled and tossed and rolled in a way that was uncomfortable, even to a good sailor. It was in the middle of the night, however, when he turned a little switch and was able to throw a flood of light into his cabin, that he appreciated the comfort of the electric light. That was what had happened to him and to many others in crossing the Atlantic. They enjoyed the comforts of daylight, and felt that the tediousness and discomfort of the passage were greatly reduced. Mr. Preece's first experience of electric lighting on board ship was in laying a cable across the Mediterranean, from Marseilles to Algiers. No one who had seen the facility that electric lighting afforded for those difficult operations connected with the laying and picking up of cables, would ever undertake the operation of submerging a cable without the adjunct of that marvellous assistant, and he was pleased to be able to say that there was not a single cable-ship now arriving in England that was not being completely fitted with electric lighting. A fleet of thirty-one ships was now maintained in different parts of the globe for the express purpose of looking after submarine cables, and the ships were all fitted with that contrivance. The ferry-boats across the Hudson River in connection with the Pennsylvania Railroad were all fitted with electric lights. He had also crossed from Boston to New York, taking the water at the Fall River, and journeying by the steamer "Bristol." In all the state cabins, saloons, and passages, the Edison light was constantly burning, and the arrangements were of a perfect character. A special engine-room was apportioned for this purpose; there was duplicate plant of engines and dynamos, and two hundred and fifty 16-candle lamps were scattered over the ship. The "Aurania" was fitted up by Messrs. Siemens, and it might be reasonably anticipated that a ship fitted by so eminent a firm would have all the appliances that science and skill could furnish. There were six hundred lamps worked by two three-hundred-light self-regulating dynamo machines of Siemens patent, each driven by an 8 (nominal) HP. (Caledonia) steam-engine, by means of ropes and grooved pulleys; and two 60-light dynamos of similar construction, each driven by a 4 (nominal) HP. Tangye vertical-engine. Those engines and dynamos were used specially for the engine-room and the stoke-hole, and for what were called police-lights. They started from the moment the ship left New York, and continued running until her arrival at Liverpool, and during the whole of that time not a single flicker was observed; the lights were absolutely and perfectly steady, and at all times and seasons every part of the ship was thoroughly illuminated. There were, however, two or three defects in the saloon arrangements, which were due to bad joints. The Author had pointed out the modes by which the electric currents could be distributed throughout a ship; of course, in all these cases, the ship was really lighted by the coal burnt in the furnace; the energy developed in the furnace was, by means of the engines and of the dynamo, converted into that form of energy called electric currents, and when those currents passed through a thin carbon filament they developed the other form of energy called light. The currents were distributed either by the one-wire system described in the Paper, Mr. Preece.

Mr. Preece. where the return was the shell of the ship, or they might be distributed by means of two wires—a method justly praised by Dr. Hopkinson. Again, they might be distributed by three wires, according to the mode employed by Mr. Edison in America, but also invented by Dr. Hopkinson for other purposes in England. It was essential in an installation of electric lighting, to have the currents so distributed as to have an equal pressure all over. On board ship, and in a private house, a continued service was required, so that, in case of accident or disturbance of any kind, by turning on a little switch an energy could be elicited that would flood the whole cabin or room with light. Bad joints and leakage were a frequent source of trouble on board ship. Even on board the "Aurania," when the ship rolled from side to side, one chandelier after another went out. The result was due to the ignorance, not, of course, of those who ordered the work, but of those who carried it out. It was a great satisfaction to know that electric lighting was improving, and that it was favourably received by the members of the Institution.

Mr. Swan. Mr. JOSEPH W. SWAN remarked that, looking at the incandescent lamp from a theoretical point of view, it was difficult to understand why as large a return of light for a given expenditure of electric energy should not be obtained from the white-hot filament as from the glowing crater of an arc lamp. In both cases the source of light was the same—electrically heated carbon. From the circumstance that the incandescent filament was not cooled by air currents, and the carbon of the arc lamp was so cooled, even a larger return of light from the filament might be anticipated; and this anticipation was not less warranted by the fact that the whole mass of the filament was uniformly heated, and that its entire surface emitted light, while the pencil of the arc light was unequally heated, and only a small part of its surface, to the degree of incandescence. Experiment confirmed this deduction. He had measured the light of an incandescent lamp when it was giving at the rate of close upon 2,000 candles per electrical HP., or a candle for less than ½ watt. That was a larger return for energy expended than was usually obtained from a small arc; but it was all he could do to take the readings before the filament gave way under the disruptive action which attended this exceedingly high temperature. The practical lesson of this experiment was that, if the carbon filament of an incandescent lamp were heated to an excessive degree it would not last. On the other hand, he had had reported to him the case of an electric-light installation in which

Mr. Swan.

a considerable number of the lamps had been in action during five thousand eight hundred hours, and they were still in use. He did not know the energy consumed for the light given in this case, but he felt pretty sure the lamps had not been highly heated. Probably as much as 4 or 5 watts instead of ½ watt had been expended for every candle-light obtained. The question at what point between these extremes the cost of maintaining a certain required quantity of light would be least, was undoubtedly one of the greatest importance in relation to the economy of electric lighting by incandescent lamps. It was one which involved many varying conditions, and it had not yet been answered. To answer it completely, a number of carefully performed experiments were required, with numerous lamps of different kinds, lighted by currents of different kinds and strengths, constantly maintained for a considerable length of time. Experiments of the required thoroughness had never been made, and he doubted if really much more was known than that when the rate of 3 watts per candle had been attained, the lamp was living a fast life which would not last, and that below 4 watts per candle, and the lamp was not constitutionally bad, a green old age might be predicted for it. This he knew perfectly well was far from being a precise statement, but in the present state of knowledge it would not be safe to make it more precise. The question, however, was being considered in relation to ship lighting, and there it was evident what ought to be done. The two chief elements in the question were, the cost of lamps and the cost of power. Where power cost little it was more economical and convenient to take a small return of light for power expended, than to exact a large return at the expense of more frequent lamp renewals. This was the case in ship lighting; for whether an amount of light equivalent to 200 candles per electrical HP., or only 100 candles, was obtained, did not greatly affect the cost of light on board a steam-ship where 1 HP. was developed by 2 lbs. of coal. Suppose, for example, that two hundred lamps were installed on a certain ship, and that all were lighted during an average of five hours a day, winter and summer—a length of time sufficiently in excess of the actual time to compensate for the few lamps lighted during additional hours. Assuming the indicated HP. to be developed by 2 lbs. of coal, and that there was a loss of 33 per cent. in transforming the mechanical energy into its electrical equivalent in the lamps, it would result that from 3 lbs. of coal 100-candle light would be obtained during one hour in one case and 200-candle light in the other; or, to

Mr. Swan. sum up the time and the coal so as to ascertain the cost in larger figures:—Every ten lamps expended 746 watts, and required 3 lbs. of coal per hour; 60 lbs. per hour for two hundred lamps, and 300 lbs. for the five hours a day, or nearly 1 ton of coal per week. Then, to get the same amount of light with such a low temperature of filament that only 100 candles per 2 HP. resulted, just twice this quantity of coal would be consumed, namely, 2 tons per week instead of 1 ton—a quantity so small that the breakage of a few lamps every week would more than equal its value. Or, supposing the average life in one case to be five hundred hours, and in the other five thousand, it would certainly be more economical to burn the larger quantity of coal and to have fewer lamps to renew. What the precise result would be in these two cases could not, as he had said, be stated with minute accuracy, for a good deal depended on the cost and quality of the lamps. But this at least was evident:—the total cost of coal consumed was so small in either case, that if any considerable increase of longevity in the lamps, from, say, hundreds to thousands of hours, followed from the lower rate of light efficiency, and he did not doubt that would be the result, it would, on the whole, be better to burn the extra ton of coal per week in order to reduce the cost and trouble attending the renewal of broken lamps. He therefore thought that for lighting steamships it was advisable to maintain the lamps at a moderate temperature.

With regard to the two modes of distribution described by the Author, he concurred in Dr. Hopkinson's view that the two-wire system was the safest, and therefore the best. It was impossible to be too careful to ensure the maintenance of good insulation in the conductors, and there could be no question that the two-wire system contributed to that condition. Not only the wires, but the dynamo and the lamp-fittings should all be insulated from the skin of the ship. Where wires passed through iron partitions, the holes should be bushed with wood or other insulating material. He passed from these cardinal points to notice two minor details, namely, switches and fusible bridges, or cut-outs. There were numberless designs for these small but indispensable appliances, and both in design and construction he thought many of them were susceptible of improvement. A switch for a ship should be strongly made, and so simple and sure in action that it could not by any possibility get out of order. In his opinion there ought not to be any combustible material about it. The base to which the metallic fittings of the switch were attached should be earthenware, or some material as incombustible as earthenware. He said the same **Mr. Swan.** of fusible bridges, which should be fixed at every junction of a branch with a trunk wire. To render these the complete protectors they were intended to be, they should be both well designed and carefully fitted. Lead wires should never be used, unless the ends of the copper branch wire into which the piece of lead wire was inserted were soldered to the ends of the lead wire. If this could not be conveniently done, and he thought possibly it could not, then lead must not be used, for it was so soft, and so prone to oxidation, that it was impossible to make, or at least to preserve, good contacts between it and the ends of the wire by means of nuts and washers, however firmly they might be screwed "home" at first. A much better metal for the purpose was tin. It was more fusible than lead, less readily tarnished, had almost as high a specific resistance, and was sufficiently hard to enable a good contact to be made by means of screw connections. Tin could be drawn into excellent wire for this purpose, or pieces of a proper size and form, with enlarged ends or lugs, could be stamped out from sheets of pure tin. These were small details, but they had an important bearing on the safety, the efficiency, and the permanence of a system of electric lighting on board ship.

Mr. Mance. Mr. H. C. Mance, C.I.E., said the Author had stated that one hundred and fifty ships had been fitted with the electric light. It would be interesting to learn if the electric light was still used on all these ships, or, if not, the reason of its discontinuance. No doubt a great many blunders had been made in some of the early installations, and if they were ascertained they might be avoided in future. He could testify to the ease with which the electric light was kept in order on board ships. He was frequently on board the "Patrick Stewart" Government telegraph steamer, stationed in the Persian Gulf, which had been fitted by Messrs. Siemens, about six years ago, with a continuous-current dynamo machine, suitable for a 1,000-candle arc lamp. The dynamo stood on a small platform just over the entrance of the shaft tunnel, and the arc light was on the bridge. It had not been moved for six years. It was not often used, but it was always ready, and beyond the expense of the carbon, it had not cost a penny for maintenance. It was occasionally employed when the cable work was prolonged into the night to get the final splice overboard, and in that way it was of great assistance. When he returned to India he should take with

Mr. Mance. him the necessary appliances to fit up incandescent lamps in the cable-tanks.

As the question of joints had been mentioned, he might refer to a very small joint used in the Persian Gulf Telegraph Department, which might, he thought, be found of advantage to those who were entrusted with installations at home. He referred to joints above water. They were small india-rubber joints, which had been sent out for their india-rubber cable in small air-tight cases, so that one or two could be used as required. The copper conductor was first soldered, and the dielectric pared down to a taper on both sides. The jointing material consisted of a strip of pure india-rubber, a separator, which was very adhesive, and a red jacket. These strips were applied in succession, and the joint could be made in a few minutes. He had, as a temporary measure, put them down in 40 fathoms of water, and he had never found them give way. They were generally used to connect leads in cable boxes in the harbour, where the water rose within 6 inches of the cable ends. They had given no trouble, and he had found them very serviceable. The cut-outs mentioned by the Author were no doubt correct in principle; but he thought that mechanically they were not exactly suitable for adoption on board ship. Those who were aware of the amount of cleaning and wetting that went on on board ship would know how important it was that the cut-outs should be safe from meddling and be dry, so as to avoid any surface leakage. He had occasionally used cut-outs to protect the cables from the effects of lightning. When unprotected, the delicate platinum spirals were easily broken, but they could be preserved by enclosing them. A cut-out should be dry, but at the same time easily visible. He had recently been shown the drawings of one which was protected by a little glass, so that it could be seen if any damage had occurred. It was contained in a piece of ebonite 2 inches long and 1 inch square, so that it would not interfere with the running of the wires along the ship's side. He presumed that the Author meant, referring to insulation, 10 megohms per knot. Beginning with that it would be nearly certain to come down to less than 1 megohm per knot in the course of a year or two. The system of embedding in a grooved paraffined board was no doubt excellent, but it was not always practicable. By applying a serving of tape with india-rubber solution, the gutta-percha leads lasted three times as long. He had great trouble at one time with leads for testing purposes, in which he required greater insulation than would be needed for lighting, **Mr. Mance.** and he found that the addition of the tape gave excellent results. With 10 megohms per knot it was evidently intended to have a thin dielectric; there was therefore the more reason for protecting it thoroughly, so as to prevent any mechanical injury. He had tried many things, and he thought that a tape immersed in a mixture of white lead and tallow, which had been boiled carefully, formed an excellent and cheap perservative. He was surprised that nothing had been said about storage batteries. Was it to be understood after all that had been written on the subject that storage batteries were not of the slightest consequence? He was inclined to think that, at any rate for small installations, they would lead to an enormous extension of electric lighting. Of course, what was wanted was a simple, cheap, durable, and efficient storage cell.

Mr. FRANK WYNNE referred to the statement in the Paper that **Mr. Wynne.** the expense of the maintenance of electric lighting was not much in excess of the older methods of illumination. That was a point upon which it was very difficult to get satisfactory information. The estimates received of the cost of the earlier methods varied from 100 to 150 per cent. Those variations not only applied to ship lighting, but also to railway lighting. He had hoped that the Author would have been able to give some trustworthy details on the subject. With regard to driving by iron gearing, he might mention that in the case of a Mexican ship fitted with machines, it was found to answer very well. No doubt, however, it was a severe trial to a machine to be driven by cast-iron gearing, to say nothing of the noise; and when there was an excellent system like that introduced by Messrs. Siemens Bros., known as the Raworth gearing, he did not know why it was not more generally adopted. It had been suggested, and he thought that the suggestion was a very practical one, that the driving-wheel should be the soft surface, and not the driven wheel. That seemed very rational, because otherwise there was a danger of a facet being cut upon the driven wheel. Mr. Wynne was in favour of direct-driving machines. That was the best method for quick speed, but the company with which he was connected had systematically adopted low-speed dynamos, as getting over all the difficulties connected with shafting and belting. He had expected to hear more as to what had been done with driving by ropes, and he hoped that the Author would say something on the subject. He believed that low-speed dynamos were unquestion-

Mr. Wynne. ably the best. Attention had been directed to the characteristic curve, nearly straight, of the Victoria dynamo (Fig. 1). It might have been made perfectly straight. The electromotive force was permitted to drop slightly as the current diminished, both to allow for the decrease of loss in the leads, and also for any momentary acceleration of speed in the engine where suddenly relieved of a large portion of its load.

Mr. Farquharson. Mr. J. Farquharson observed that the Author of the Paper had made some reference to what was being done on board men-of-war; and as he knew more about those ships than about merchantmen, he might be allowed to state that the Author was rather in advance of the actual state of the case in saying that no man-of-war now left the builder's hands without being lighted electrically. There were but three fighting ships in England so lighted. The first lighted by the incandescent system was the Brazilian ironclad "Riachuelo," and since then two other ships in the navy had been fitted, the "Polyphemus" and the "Colossus." A great many transports and troop-ships had been lighted, and he was able to give some particulars of the results obtained in one or two of them. During the last year and a half five large Indian troop-ships, the "Malabar," "Crocodile," "Serapis," "Jumna," and "Euphrates," had been lighted, and the Imperial troop-ship "Orontes." The five large troop-ships had an installation of about four hundred lamps each, and he had some particulars of the cost of two of them, which had been carefully prepared with a view of showing how the cost compared with that of ordinary lighting. Before reading the statement, he might remind the members that it ought not to be assumed that the cost of lighting ships in the Royal Navy by the ordinary system was fairly comparable with the cost of lighting other ships. No mineral oil, for example, was allowed in ships of the Royal Navy, and the colza and olive oil used in them was more costly, so that the comparison would not be the same as that with private ships.

Details of the Cost of Lighting H.M. Indian Troopship "Crocodile," for Ninety days, by the Old and New Systems, viz. Candles and Oil, and Electricity by Incandescent Lamps.

The number of lamps by each system was about the same. The actual number of incandescent lamps was four hundred and thirty-eight. They were of two sizes, viz. 10-candle power three hundred and seven, and 16-candle power one hundred and thirty-one. It would be seen by the details of cost that the bulk of the ordinary lamps were candles, and the proportion of light would therefore be electrically greater as 10 to 1 or thereabout.

Mr. Farquharson.

Details of Expenditure.

New System.—Incandescent Lamps.
Details of Material.

	£.	s.	d.
Coals, 112½ tons at 15s. per ton	84	7	6
Cotton waste, 90 lbs. at 27s. per cwt.	1	1	8
Oil (Mineral), 180 gallons at 1s. 2d. per gallon	10	10	0
„ (Olive), 23 gallons at 3s. per gallon	3	9	0
Lamps replaced, 35 at 3s. 6d. each	6	2	6
Lamp globes, 15 at 3s. each	2	5	0
Fusible wire plugs, at ¼d.	0	1	8
Depreciation on plant, at 2½ per cent.	12	0	0
Total	119	17	4

Old System.—Candles and Oil.
Details of Material.

	£.	s.	d.
Candles, Stearine, 250 lbs. at 32s. 4d. per 50 lbs.	8	1	8
„ Police lamps, 1,300 lbs. at 32s. 4d. per 50 lbs.	42	0	8
„ Fighting lamps, 1,750 lbs. at 34s. per 50 lbs.	59	10	0
„ Signal, 1,430 lbs. at 34s. per 50 lbs.	48	12	0
Oil, Colza, 493 gallons at 2s. 3d. per gallon	55	9	3
Wicks, Cotton, 160 at 1½d. per doz.	0	1	10½
Cotton balls, 8 lbs. at 8½d. each	0	5	8
Chimneys	0	4	0
Depreciation of plant, at 2½ per cent.	3	14	0
	217	19	1½
Abate value of cases returned	4	14	0
	213	5	1½
Total cost of new system	119	17	4
Difference in favour of Electricity	93	7	9½

Or £377 per annum.

The labour on the two systems was practically the same.

The statement took no account of labour by the old or by the new system, the fact being that no additional labour was allowed. Two engine-room officers were told off to attend to the dynamos and the incandescent lamps, and since as many lamp-trimmers would be employed on the old system, the cost for labour would be approximately the same.

He had received the subjoined return relative to the electric lighting of H.M.S. "Malabar," from which it would be seen that it was possible to make lamps that would last more than six thousand hours.

Mr. Farquharson.

NUMBER of HOURS ELECTRIC LAMPS have been BURNING in the different CIRCUITS on H.M.S. "MALABAR," and the NUMBER of LAMPS which FAILED in each from various CAUSES, from AUGUST 6th, 1883, to OCTOBER 31st, 1884.

Circuits.	Number of Lamps in Circuit.	Number of Hours.	Lamps Broken from the undermentioned Causes.					Remarks.
			Plaster Soft.	Fibre Broken.	Accidental.	Collapsed.	Total.	
Saloon deck aft, day . .	54	1,736	1	6	2	2	11	The average life of the 130 lamps which failed from breaking of fibre, or collapsing, was 3,799 hours each: the shortest life being 638½ hours for 8 yard-arm lamps of 32 C. P.
" " " police . . .	19	3,950¼	..	4 and 1 (32 C. P.)	1	..	6	
" " forward, day .	30	1,030½	1	3	..	..	4	
" " " police .	27	3,912	4	23	9	..	36	
Main deck aft, day . . .	28	1,769½	1	..	..	..	1	
" " " police . .	6	4,506	..	4	1	..	5	
" " forward, day . .	86	901	65	8	14	1	88	
" " " police .	17	3,953	9	5	3	..	17	
Lower deck aft, day . . .	25	1,733	..	1	1	..	2	
" " " police . .	6	5,763	..	3	..	..	3	
" " forward, day . .	34	791¼	17	13	3	1	34	
" " " police .	5	3,820	4	4	1	..	9	
Engine-room	37	6,322	16	29	19	10 and 2 (32 C. P.)	76	
Store rooms	10	5,793½	1	2	1	..	4	
Starboard yard-arm . . .	8 of 32 C.P.	638½	..	7 (32 C. P.)	2 (32 C. P.)	1 (32 C. P.)	10	
Port yard-arm	8 of 32 C.P.	316½	..	..	6 (32 C. P.)	..	6	
Broken in lamp-room . .	..	..	..	..	4	..	4	
Total . . .	400	..	119	113	67	17	316	

He had also another return which he thought would be interesting to the members.

Mr. Farquharson.

Number of Incandescent lamps worn out from various causes, and replaced in H.M. Indian Troop-ship "Malabar" between the 6th August, 1883, and 16th February, 1884, viz., one hundred and eighty-three days; and the number of hours each lamp had been burning: the total number of lamps in the installation being three hundred and eighty-four.

Number of Hours Burnt.	Cause of Failure.				
	Plaster Softened.	Fibre Broken.	Collapsed.	Accidental.	Total.
488	12	11	1	2	26
543	40	2	1	5	48
613	1	1	..	..	2
995	..	..	..	1	1
1,019	1	3	2	2	8
1,042	1	..	..	..	1
2,193	1	3	..	1	5
2,226	6	2	..	3	11
2,254	4	13	..	6	23
2,259	..	..	..	1	1
2,431	..	..	..	1	1
2,994	..	1	..	..	1
3,558	1	1	..	..	2
3,698	8	9	6	11	34
Total . .	75	46	10	33	164

Summary—Failure of fibre	46	Total from actual use, 56.
Collapsed	10	
Accidental	33	
Softening of plaster . . .	75	

The mean life of the fifty-six lamps broken in actual use was two thousand and sixty-three hours. The cost of the lamps exclusive of the seventy-five which failed from a defect in manufacture, which defect had since been remedied, viz., eighty-nine at 5*s.* (being the increased price now charged for them), was £22 5*s.*, or £44 10*s.* for the whole year on an installation of three hundred and eighty-four lamps.

Mr. Farquharson.

An allowance had been made of 2½ per cent. for deterioration of plant by both systems of lighting. The choice of position for dynamos, so far as ships of the Royal Navy were concerned, was limited. There were no unappropriated spaces in a man-of-war, and the question of lighting had not been considered when the ships were built. There was a choice of two or three places, none of them being very good; but it had never been necessary to put the dynamos athwart ships, and so far, with very few exceptions, there had been very little injury to the dynamo from gyrostatic action. He did not know what the Author's object was in his statement with regard to the selection of dynamos; but if intended for the guidance of those who knew nothing about them, the better way would be to specify distinctly the work to be done, and the conditions under which it was to be done, with the limits of weight and size. The Author had stated that dynamos underwent an insulation test of 10,000 ohms per volt generated. It was certainly not expected to get anything of that kind in the ships of the Navy. After a dynamo had been running for some hours in the vapour of steam, and in a generally moist condition, it was considered satisfactory if no blue sparks could be got in the dark by taking a wire from one of the brushes to the frame of the machine, the frame of the machine being connected with the ship. So far there had been no failure in a single instance. With reference to the speed of the dynamo in the navy, gearing of every description was avoided, all the dynamos being driven direct. In former years some of the dynamos were driven by gearing, but the practice had been entirely discontinued. It was now considered that the proper speed of a dynamo was that which would secure a lasting and economical engine, and with that view it was thought that for dynamos which might be expected to have a load of from 16 to 18 HP. four hundred revolutions was a good speed, and there was no difficulty in obtaining good engines to work at that speed. The result, judged by the amount of work done by the power absorbed, would be the same with that or a higher number of revolutions per minute, but the cost was necessarily more; and it might be taken that the cost of a low-speed dynamo was increased about 40 per cent. Comparing it with a dynamo running at one thousand revolutions doing the same work, 40 per cent. more would have to be paid.

As to the governing of an engine, no difficulty had been experienced. He was not aware of the failure of a single lamp from extra stress put upon it through the increased speed when the load was lightened. It had been stipulated that the system should be capable of allowing 90 per cent. of the lamps being turned out without any extra strain being put on the remainder. That was one of the tests applied to ascertain whether the stipulation in the contract had been kept, and there had been no difficulty in accomplishing it. The speed of the engine, when all, or nearly all, the lights were taken off, was somewhat increased, but well within the limit given by the Author. The engines were governed sufficiently at that low speed so as not to exceed twenty-five revolutions more for a moment than with the whole load. He thought, therefore, that electric governors were unnecessary. In the Navy, ships were wired on the double system, with one exception, but he knew no good reason why it should be adopted. Electricians were asked to believe, without any reason, that it was easier in the one case to connect the wire with the skin of the ship than in the other to connect the two wires. He had never been able to learn that the work by the one system was more liable to derangement than by the other. The Admiralty had a ship wired on the three-wire system, and it had turned out to be the worst of all. He might mention what happened in practice. After coaling, the hose was turned on, and leakage took place in the casings, and water lodged in the grooves, which soon destroyed the dielectric, forming, as the Author had described, sub-chloride of copper, and soon corroding the wire. Surely two wires were more liable to injury of that kind than one wire. Government had spared neither money nor time in trying to avoid that leakage, but had not entirely succeeded in a single instance. They were now about to do something in the hope of preventing it, namely, to sink the grooves one and a half time the diameter of the wire, completely filling in the groove with a composition of 80 parts of common putty, and 20 of white lead. That did not shrink or crack much, and it would at any rate have the effect of preventing the lodgment of water, whether with the one-wire or the two-wire system. If by any means the water could be kept out, more would yet be accomplished. With reference to fusible cut-outs, he was glad to hear that Mr. Swan advocated tin wires; but the Author appeared to be under the impression that cut-outs were needed for a purpose not at all contemplated in the Navy, namely, the saving of the lamps. By a properly-balanced compound-wound machine, no trouble was experienced in that respect. In the event of a nail being driven in to hang the cook's ladle upon, unless there was a cut-out in the branch the wire would be heated, which Mr. Farquharson.

Mr. Farquharson.

might ignite the casing. The cut-outs were for the purpose of opening a circuit in case of its being shortened. A cut-out was put in every main, in every submain, and in every branch to prevent extra heat and ignition from an accidental cause. He should like to know from the Author whether he should expect that lamps burning with small currents in a high state of incandescence would last relatively as long as those burned in a lower state of incandescence. He had had very little experience with it, but he believed that the nominal candle-power in the ships of the Navy was well maintained.

Mr. Mair.

Mr. J. G. Mair asked Mr. Farquharson what type of governor gave such a remarkable result, as to allow the shutting-off of 90 per cent. of the lighting with so small a variation of speed?

Mr. Farquharson.

Mr. Farquharson said it was not the question of a governor, but of a dynamo and governor. The engine generally used was a Brotherhood; it had done good service and borne a great deal of hard wear. In the "Himalaya," the dynamo and engine had been running almost constantly for two years, and had cost scarcely anything. The dynamos were Siemens alternating, the only case they had of alternating dynamos. The men-of-war were peculiarly situated as to the kind of dynamo used, because the dynamos were required to do two things, to be able to give a search light of 25,000 candles, and to light a certain number of incandescent lamps when not wanted for that purpose. In all the fighting-ships using the search-lights, there were direct-current dynamos. The dynamos in the "Himalaya" had an exciter, which was of the Siemens S.D. type. It had been running constantly for two years, and had not had any repairs done to the commutator, which might be considered very good wear.

Mr. Siemens.

Mr. Alexander Siemens wished to say a few words as to the curve of the compound machine (Fig. 1). It was not a good specimen of a self-regulating machine, no account having been taken of the resistance of the leads. To make this evident, let it be supposed that a current of 100 amperes had to traverse leads, having the resistance of $\frac{1}{10}$ ohm before reaching the lamps. In this case the difference of potential at the terminals of the machine must be 10 volts greater than the difference of potential at the terminals of the lamps. Again, if a current of only 1 ampere was to traverse the same leads, the difference of potential at the terminals of the machine need only be $\frac{1}{10}$ volt greater than at the lamps. A good self-regulating machine should, therefore, give a greater electromotive force when the current increased, the ratio of

Mr. Siemens.

the increase depending on the resistance of the leads and the maximum current.

With reference to the lighting of the "Aurania," Mr. Preece had complained first, that the pressure of the mains was not equal in all parts of the ship. To a certain extent that was true on the single-wire system. The lamps nearer the machine would have a little less resistance in circuit than those further off; but seeing that the resistance of the main was so small that difference of potential could be neglected. But had Mr. Preece taken into account that unavoidably the lamps were not absolutely equal? Lamps of 20-candle power of nominally 100 volts would require from 98 to 102 volts, a greater difference than that caused by the resistance of the wires, so that when lamps burnt a little less brightly in one part of the ship than in another, it was probably more the fault of the steward than of anybody else. He was sorry Mr. Preece had complained of the joints, and he would take care to have the matter looked into. The chandeliers in the saloon had not been supplied by Messrs. Siemens Bros., and additional lights had been put up by the owners since the installation had been handed over to them.

He thought the Paper, and a good deal of the discussion, had been rather too theoretical. The Author had begun with a short statement of the advantages of electric lighting on board ships, but he had left out the greatest advantage: that it was now possible, for the first time, for marine-engineers to see the engines working; and they appreciated this, as proved by the lights on board the "Aurania" having been at work in the engine-room from the time of the ship's leaving Liverpool until her arrival at New York. With reference to the requirements of dynamos and steam-engines for a ship's installation, the Author had stated the theoretical requirements, but not the practical ones, viz. that the dynamos and steam-engines should both be constructed for rough usage, and should be capable of being easily repaired even at sea, by ship's engineers, and that above all they should be amply powerful for their work. A dynamo which was supplied for two hundred lamps regularly, ought to be able at a stretch to light at least two hundred and twenty without being damaged in any way, and the Author and other engineers would confer a great benefit on electric lighting if they rigorously required contractors to supply large engines and large dynamos. He thought it would be unwise to give up putting a fuse to every lamp; if a fuse were only put to a group of lamps, and an accident happened to one lamp, the whole group would go out, and the

Mr. Siemens. engineer would have to hunt over twelve circuits instead of over one to find out the defect. That was also a practical consideration. Reference had been made to the disadvantage of the single-wire system. One of those disadvantages was stated to be, that if salt water got in chloride of copper would be formed, and the lead destroyed, but he begged to submit that that applied as much to the double-wire system, because no dynamo-machine was ever so completely insulated from the ship that there was no leakage. Mr. Farquharson had pointed out how close together the two wires necessarily were, because there was so little head room, and many other things had to be accommodated. In the case of Her Majesty's ships, and sometimes in the case of ordinary ships, Mr. Farquharson's remarks, that in the single-wire system the wire was near the skin of the ship, would be applicable; but in general it was not, as the wire was on the average 18 inches from the skin of the ship. In a passenger steamer the iron beams were covered with wood; there were panels of wood everywhere, and if any one had injured the insulation of the single main he would have some difficulty in finding the skin of the ship to make a short circuit. In every ship, when it was wanted to make the connection from the lamp to the ship's skin, a considerable distance had to be traversed. He therefore thought that the danger to the single-wire system was entirely theoretical, and that that system was much safer than the double-wire method, where the two wires being closer together could easily be short circuited. Then there was not half the resistance in the single-wire system, because the skin of the ship being of very large extent had virtually no resistance. That meant that if in the one case 10 per cent. of the power was lost, in the other it would be only 5 per cent., and from a scientific point of view all waste ought to be avoided. Another point, not mentioned in the Paper, was the desirability of working the small auxiliary motors on board ship by means of electricity, as there was much trouble with the steam-pipes which led from the boilers to the steam-engines. This would be entirely avoided if their place was taken by the leads to the electrical machines.

Mr. Hedges. Mr. KILLINGWORTH W. HEDGES had recently examined the action of the electric-lighting machinery on board ship, during a voyage to New York and back, which he had made in two steamships of the same line. Each was fitted with apparatus, supposed to have all the most recent improvements. One of them had an alternating-current machine with an exciter on the same shaft, and the other a compound-wound machine. The alter-

Mr. Hedges.

nating-current machine gave considerable trouble, but the compound-wound was more satisfactory. During both the outward and homeward trips the lights were worked perfectly, and there was no breakdown nor hitch. He made careful inquiries as to how they behaved on former voyages. The drawback of the alternating-current machines seemed to be chiefly due to the large size of the armature. When there was any play in the bearings, the armature had a tendency to touch one side or the other, and although probably actual contact was hardly made, some of the coils were burnt. He did not think that the plan of putting an exciter and the dynamo on the same shaft was to be recommended for ship-work. It appeared that the power expended was so much greater at one end of the shaft than at the other, that there must be an unequal wear of the bearings, and consequently a tendency in the shaft to get out of line and throw the armature over. The machine was placed in the ship in the manner advocated by the Author, fore and aft, but the compound-wound machine was put across the ship. Another fault common to both machines was the deficiency of the lubricating arrangements. As the machines were placed on board they had the ordinary oil-cups and oil-holes in the centre. When the ship heeled over the oil could not get to the top part of the bearings, and there was a difficulty in keeping them lubricated, especially if there was a wind on one side maintaining the ship at an angle for some time; so that other oil-holes had to be drilled. A simple remedy would be to have a wick underneath, and to put the oil in a cup, something like what was done in the case of railway axles, so that the oil would be sucked up and spread over the shaft equally. The governors were not good, and were not in action, although the engines were fitted with what were considered very efficient mechanical governors. That seemed to be not so much the fault of the governors as of the way in which they were driven, namely, by a belt which was difficult to keep in order on board ship; the consequence was that they were so unreliable, that it was thought better to keep a man on watch constantly, to turn down the steam in the event of the engine attaining too high a speed. The dynamos were driven by rope-gear which seemed to work well. That also gave trouble at first, but the principal difficulty of keeping it dry was overcome by coating it with black lead and tallow. Rope-gearing ought to be boxed in, as there had been a bad accident on the previous voyage from a man getting entangled by the rope. No matter what driving-gear was employed, he thought that it was better for all ships to have direct-acting engines for

Mr. Hedges. electric lighting. He had put a direct-acting engine for the electric-light installation on the "Chimborazo" in 1880, and it had been in use ever since. The Author had curtailed his remarks on the subject of the arrangements and circuits of wires on board ship, especially as to the most economical plan of enabling one portion of the ship to be lighted when the other did not require it as at night, and also when the ship was in port; nor had he said anything about the side lights of the ship, or the mast-head lights. Both the ships to which Mr. Hedges had referred had electric-lighting port and starboard lights, and they were very efficient; but there was one drawback, it was always necessary to keep ordinary oil-lamps trimmed ready for use. It was not that the officers expected that the electric-lights would go out; but although the penetration was sufficient with the electric-lights, there was an absence of diffusion, so that, if the least fog came on, the lights, instead of sending their rays seawards, threw a halo in front, red on the port side and green on the starboard side, and that bothered the look-out. The Author had referred to the most economical section of conductor to be used, and stated that he found 1,000 amperes per square inch of section to be the best. That did not seem to agree with practical working, at any rate in the United States; the Edison Company for house to house lighting in New York used a much higher rate. On the new system employed there, on cables carrying 100 or 110 amperes there were 5,000 amperes per square inch, and in the Edison two-wire system 3,400 amperes were used. The reason seemed to be that to get the best economy out of copper cable, it should be worked all day; and in order to compensate for the time when it was not being worked, and for the time when the current passing through was only equal to a few lights, it had to be worked at a rather greater current for a certain period when all the lights were on. If the insulation was good there was no objection to this plan. He was glad the Author suggested the use of foil for safety fuses instead of the unreliable wire. Mr. Hedges had advocated this practice for some time, and he thought that the plan of adopting safety fuses to save the lamps was one which might be followed with advantage. As a rule electrical engineers objected to insert fuses which should protect the lamps; but from a public point of view they were necessary. The Author had mentioned a case where fifty lamps were destroyed by the governor getting out of order. Mr. Hedges had investigated that case, and ascertained that none of the fuses were melted. If they had been put in to save the lamps, there was no reason why the harm done should have been more than the melting of a few of the fuses. Of

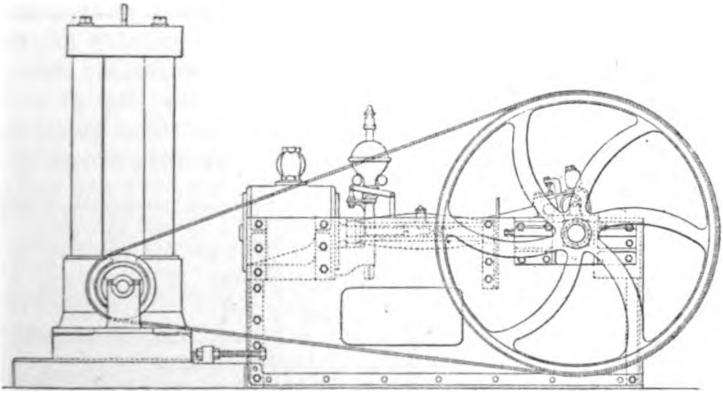
Mr. Hedges.

course there was the trouble of putting out the lights, but that was better than the large expense entailed. He used an apparatus which inserted a duplicate fuse automatically; the arrangement was designed to put in a second fuse, and so prevent the extinction of the lights, unless a short circuit occurred, when both would be melted. He was not in a position to give any information upon the cost on account of the difficulty of separating the working expenses on board ship.

Mr. Paxman.

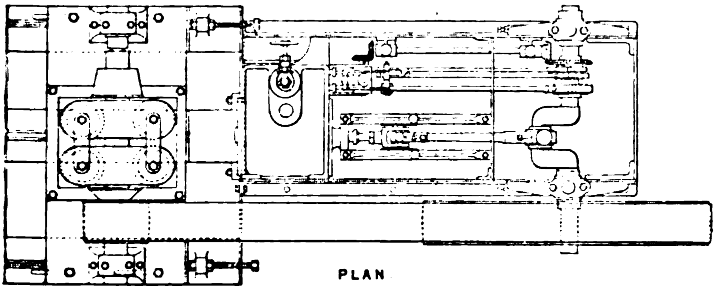
Mr. J. N. PAXMAN said that, although it could not be denied that there were advantages in high-speed engines for certain special purposes, up to the present they had not been able to compete with those of lower speed either in economy or durability. On board ship, where the stoppage of machinery was at times

FIGS. 15 and 16.



SIDE ELEVATION.

Space occupied 12'·4'-0'



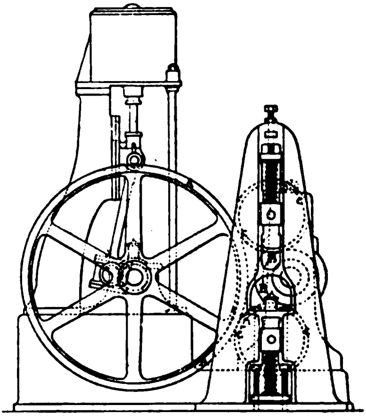
PLAN

COMBINED STEAM-ENGINE AND DYNAMO.

Scale ⅜-inch = 1 foot.

Mr. Paxman. attended with great danger to the vessel, durability and efficiency were of the first importance; repairs also were always more difficult and costly. The sacrifice of space was but small with engines and dynamos combined, as would be seen in Figs. 15 and 16. The firm of Davey, Paxman, and Co. had made several of this type; and an engine, together with the dynamo sufficiently large enough for driving comfortably two hundred lights, would only occupy a space of 12 feet by 4 feet. When it was considered that the machinery was all visible to the attending engineer; also that such engines were easy of access, and could be run for a week if necessary without stopping, these advantages were more than a set-off to the trifling additional space required. It would be noticed that Fig. 17 represented a horizontal engine, mounted upon a wrought-iron box frame forming the foundation, so as to combine lightness and strength. The cylinder was 12 inches in diameter, by 12 inches length of stroke, and the engine ran at one hundred and eighty revolutions per minute. All the parts were balanced. This engine was fitted with Paxman's automatic cut-off gear, and the governors were driven with tooth-gearing, and they would regulate the speed within 2 per cent. with all the load on or off. The dynamo attached to the engine-framing was driven from the fly-wheel with a leather belt 9 inches wide. The dynamo could be readily adjusted to keep the belt tight whilst running. Fig. 17 represented an arrangement proposed for driving a dynamo with com-

Fig. 17.



Combined Steam-engine and Dynamo.

Scale ⅜-inch = 1 foot.

Mr. Paxman.

pound friction-roller gear. A was the fly-wheel of a vertical engine; B was the friction-pulley on the dynamo; C C were two friction-wheels lined with stout india-rubber tightly forced on, or vulcanited upon the pulleys. These impinged upon the fly-wheel and dynamo-pulley, one upon the top and the other below. By this means a double grip was obtained, and the liability to slip was lessened by half. By this method, the force exerted upon the armature of the dynamo by these two wheels was nearly opposite, thus relieving it of excessive side-pressure. He desired to come to the rescue of the mechanical governor, which had received very sharp criticism from the Author, and from speakers in the course of the discussion. Two or three leading principles should be taken into account in making a governor, and they were very simple. At the Exhibition held at South Kensington, in 1884, a governor worked practically true, regulating the speed of the engine within 1 or 1½ per cent. In stating that, in low-speed engines, the governors would not run within 5 per cent., and in high-speed engines 25 per cent., he thought the Author must have fallen amongst an indifferent set, for it was not an uncommon thing to have a governor regulating the speed within 2 per cent. He had

Test of Governors combined with Automatic Cut-off Valve for ascertaining Speed of Engine under various Pressures of Steam with and without Loads, by J. N. Paxman.

60-HP. Compound Engine, Cylinders 15 inches and 22½ inches, length of stroke, 24 inches. May 1883.

Test Number.	Steam-Pressure. lbs.	Indicated HP. with Load.	Number of Revolutions.	Indicated HP. without Load.	Number of Revolutions.
1	45	83·6	102·00	17·18	103·50
2	60	128·0	102·25	18·00	103·75
3	75	137·0	102·25	17·70	103·50
4	90	135·5	102·00	17·20	103·50

20-HP. Double Cylinder, Semi-portable Cylinders, diameter 10½ inches, stroke 14 inches. May 1883.

1	40	32·0	138·00	11·5	140·0
2	50	40·9	138·00	10·0	139·5
3	60	47·7	138·50	10·4	140·0
4	70	66·0	138·75	11·2	140·5

current, as only about one-half the length of wire required for the first system suffices. The disadvantages are, that a fault in the insulator or dielectric of the leading wire has a more direct effect upon it than upon the double-wire system, for any accidental connection of the conductor with the iron of the ship at any point, short-circuits the wire at that point. It is also found that if, through the ship leaking, salt water should penetrate the dielectric to the conductor, the latter will soon be eaten through by galvanic action, sub-chloride of copper and soda being formed. Faults of this description have occurred with both systems and given considerable trouble, but with first-class dielectrics, good joints, and by carefully encasing the leads in varnished or paraffined grooved wooden casings, such accidents should not happen, as the conductor would then be protected by a waterproof casing throughout except at the switches and lamps. Plate 1, Fig. 2, plans of s.s. "Arawa" and s.s. "Tainui," are examples of ships wired on this system, but extra care and the very best insulated leading wires have been used throughout, as verified by the Author's tests.[1]

All joints in the leads should be carefully made by experienced workmen. They do not require to be so well done as in submarine telegraphy, as they have not to withstand the water-pressure, and the requisite insulation-resistance is not so high; nevertheless the metallic junctions should be thoroughly well soldered, the dielectric ends cut down to a taper with a sharp knife, and thereafter the whole covered with wrappings of felt, pure rubber, and waterproof tape, being finally varnished.[2]

It is most important that the size of the conductor should be sufficient to carry the necessary current without causing more than 2 to 3 per cent. loss of the electrical power developed in heating them. Sir William Thomson's law for bare conductors, viz., not less than 1 square-centimetre for 50 amperes, which is based on the principle that the total loss is a minimum when the two component losses are equal, *i.e.*, when the annual cost of power wasted in heating the conductor is equal to the yearly interest plus depreciation on its value, is too liberal an allowance of copper in the case of well-insulated short leads; besides which he has omitted to add the insurance on the value of the wire which, in the case of ships' fittings, amounts often to 7 per cent. The Author has used a rule which he finds to work well in practice for ships' leads where the length is never great, viz.:—

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[1] Reply to discussion, p. 90.

[2] Detailed rules for making joints in electric light leads. "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," p. 230. Third edition. Also remarks by Author previous to discussion.

"The conductor to be of best copper of not less than 95 per cent. of the conductivity of pure copper, and to have a cross section of 1 square millimetre for every ampere and a half of current passing through it (which is at the rate of about 1,000 amperes to the square inch); the insulation-resistance of the whole circuit when fitted including all switches, &c., to be not less than 1,000 ohms per volt of electromotive force generated by the dynamo."

Before fitting the wires, specimens of not less than 100 feet should be selected, immersed in sea-water, or brine-water for twenty-four hours, and then carefully tested for insulation-resistance, and not passed unless they give over 10 megohms. Specimen joints should be treated in the same way and give at least 100 megohms each.

Although the above rule for the size of conductors is considerably in excess of that required by theory for mere safety from heating, and not applicable to large and long district mains, it has been found in practice to give excellent results in small installations on board ship and in houses, where the maximum current conveyed by any leading wire does not exceed 300 amperes, and the farthest lamp is not more than 100 yards from the generator. The required sizes of the conductor are easily calculated or found direct from the Tables[1]; those for even single lamps are of sufficient size and strength for rough handling. There is not the slightest danger from heating in any part of the circuit, and the rule is economical when applied to the best class of insulated leads. Based upon this rule, in the following Table (p. 16) will be found the most common sizes of leading wires used in ship installations, and which the Author is in the habit of handing to contractors working to his specifications.[2]

It is seldom that on board ship more than 300 amperes are generated by any single dynamo; and, as several main leads usually spring from the dynamo-room to various parts of the ship, the current in any one of them seldom exceeds 100 amperes, so the wires do not vary greatly in size, and generally four sizes will suffice for a ship.

Insulation-resistance is too often neglected by electric-light engineers. Amongst submarine-telegraph engineers it is con-

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[1] "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," pp. 178, 217-222, 223-226. Third edition.

[2] Reply to discussion, p. 89.

TABLE for SIZES of SHIP LEADS (WELL INSULATED).

For Swan 20-*Candle-Power or Edison* 16-*Candle-Power Lamps.*

Maximum Number of Lamps to be carried.	For 45 to 60 Volt Lamps Requiring 1·5 to 1·1 Amperes.	For 90 to 110 Volt Lamps requiring 0·8 to 0·6 Amperes.
	Board of Trade Wire-Gauge; Branch Leads.	Board of Trade Wire-Gauge; Branch Leads.
1	No. 18 wire	No. 20 wire
2	„ 16 „	„ 18 „
3	„ 15 „	„ 16 „
10	„ 10 „	„ 12 „
	Main Leads' Strand.	Main Leads' Strand.
20	7 No. 15^{s}.	7 No. 16^{s}.
25	9 „ 15^{s}.	7 „ 16^{s}.
45	19 „ 16^{s}.	7 „ 14^{s}.
60 to 70	19 „ 14^{s}.	19 „ 16^{s}.

sidered of vital importance to watch the insulation-resistance with the most rigid accuracy, not only during the manufacture of a cable, but during its submersion and after it has been laid; whereas in the case of electric lighting, those charged with the fitting up of an installation very seldom think of, or even know how to take, insulation-tests, either of the dynamo or of the leading wires. The Author has found great difficulty, in most installations with which he has been connected, to get the contractor to recognize the importance of this test; in fact he has only met with one instance in which the contractor himself used testing-apparatus which would detect a small flaw in the insulation of the wires after they had been fitted. To this general neglect of testing conductor- and insulation-resistance may be attributed some of the failures that have occurred.

It is far from right to allow leads to be run up like bell-wires, without the slightest knowledge as to whether a flaw or a fault has crept in, and all engineers should insist upon rigid inspection, as well as thorough and searching tests, before an installation is passed. The insulation-resistance-standard need not be nearly so high as in the case of submarine cables; but nevertheless it does require to be several hundred times more than the copper-resistance, otherwise a fault will soon develop, and short-circuiting occur, under the combined influences of the electromotive force and damp or wet.

The dielectric should, therefore, in addition to being a good insulator, be thoroughly watertight, and as little liable as possible to be affected by atmospheric changes.

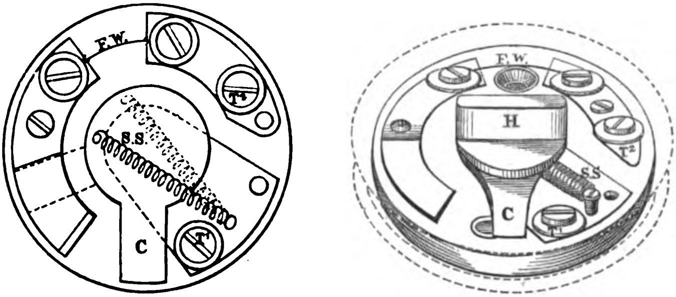
SWITCHES AND FUSIBLE JUNCTIONS.

There are three methods of arranging the main switches on board ships, the first by having all situated in the dynamo room, whereby the circuits are wholly controlled by the man attending to the engine and dynamo. The second, by having one main switch to control the whole current, near the dynamo, with the others situated where the different main circuits branch off, so that they can be turned off or on by the ship's servants as required. The third method is to have main switches, not only in the dynamo room, but also at the base of the different departments. The last plan introduces unnecessary complication, and the first can only be carried out when all the different circuits spring direct from the dynamo room. The second is more general, and serves all requirements now that self-regulating dynamos have been introduced, and if care be taken that too many of the circuits are not put in or cut out at one time, so as to overtax the powers of the engine-governor. In most installations each lamp is fitted with a switch, so that every passenger may turn on or off his light at pleasure, which is no doubt convenient for the passenger; and after the novelty has passed away there need be little fear, in a well-regulated ship, that the privilege thus afforded will be unduly taken advantage of, or the switches or lights tampered with. One of the best and simplest forms of these small switches, introduced into this country by Mr. H. C. Harold, is shown in Fig. 8. The merit of this switch is that it remains hard on or hard off as the spiral springs S S act on each side of the dead point. The contacts are scraping contacts and can be easily cleaned. Fig. 9 shows the Hammond Co.'s switch for the same purpose.

An excellent form of main switch, as fitted by Messrs. William Denny and Bros. into the Shaw-Savill steamers, is shown in Fig. 10, where double-spring scraping-contacts are provided on each side, and the lower contact projects beyond the upper one, so that any accumulation of dirt due to "sparking" on opening or breaking circuit may be readily removed by cleaning it with emery-cloth.

Fusible or safety wires should be introduced into all the main and branch circuits. The size for the branch circuits being such that they will give way before the current becomes dangerously

Fig. 8.

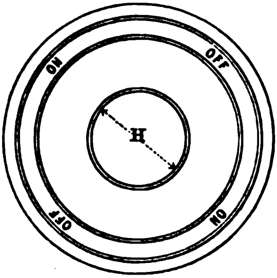


The Lundberg Improved Electric Light Switch.

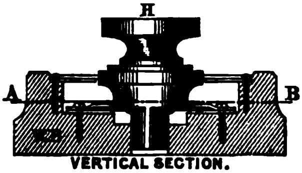
C, Contact Tongue, which may be turned to right for contact and to left for free by handle H. S S, Spiral Spring, which keeps C hard on or hard off. T^1 T^2, Terminals to which the leading wires are attached. F W, Fusible Wire, generally composed of tin or of composition metal.

Fig. 9.

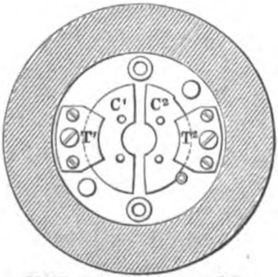
HALF FULL SIZE.



OUTSIDE PLAN.



VERTICAL SECTION.



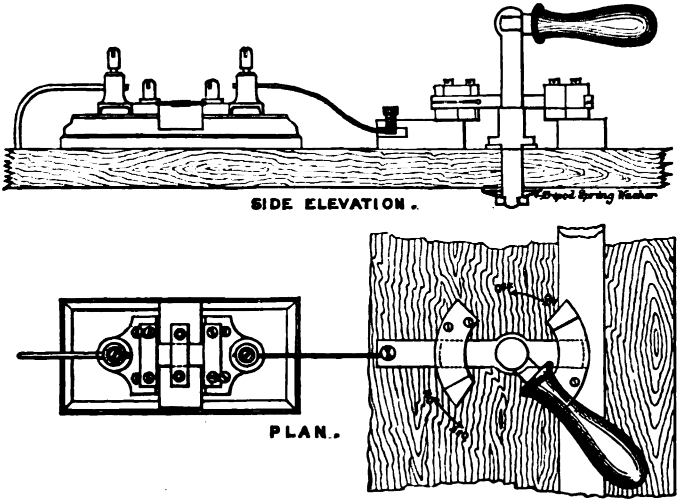
SECTION PLAN THROUGH A.B.

The Hammond Electric Light Co.'s Switch for Branch Circuits.

H, Handle. C^1 C^2, Contact Plates. W B, Wooden Base.

strong for the smallest leading wires of the section. In most instances the small safety "cut-outs," which some firms introduced in circuit with each lamp, did not act so as to save the lamps from destruction. To guard an Edison or Swan lamp, requiring 1 ampere or less, from breaking through excess of current, the fusible wire, to be of real use, would have to be so very fine as to be difficult, from a mechanical point of view, to handle or replace. A neat method of overcoming this mechanical difficulty has, however, been fitted into the s.s. "Manora." A thin narrow strip of tinfoil in the form of a double hook or S, is pasted on a piece of insulite, to stiffen and support it, each end of the S being fixed down by means of a screw, whereby the current feeding the lamp has to pass through the tinfoil. Its dimensions are such that it will fuse with about twice the normal current required for the lamp.

Fig. 10.



Main Switch Arrangement, s.s. "Arawa," with Hedges' Fusible Bridge.

Scale ¼.

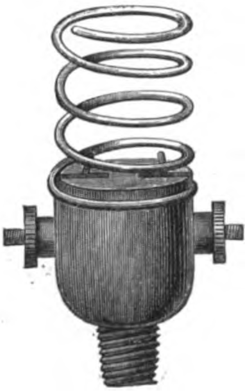
All fusible wires or "cut-outs" should be so fitted that they can be readily inspected and replaced by fresh ones when required. They should be as short as practicable, so as to increase the resistance of the circuit as little as possible.

Lamp-holders, Lanterns, and Globes.

In choosing the kind or form of lamp to be used, there is so little difference between the efficiency and lasting powers of those of the different makers, that the chief things to be attended to are, that they should be of the required candle-power when supplied with the current and electromotive force of the selected dynamo.

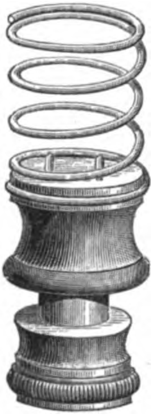
Lamps of 10-candle power are sufficient for most cabins, of 20-candle power for saloons, music-rooms, smoke-rooms, boiler- and engine-rooms, and of 50- or 100-candle power lamps, for side-lights, masthead-lights, gangways, and hatchways, or a cluster of 20-candle power lamps.

Fig. 11.



For Double Wire Circuit.

Fig. 12.



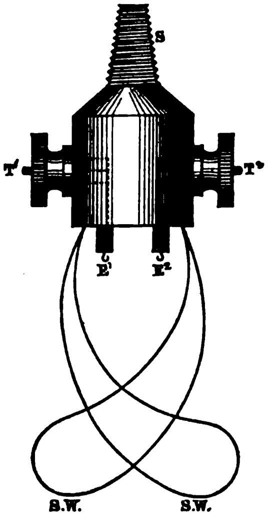
For Single Wire Circuit.

Messrs. Siemens' Terminals for Swan Lamps.

It is important that the holders for the lamps should enable good, easy, but firm contacts to be made between the terminals of the lamp and the leads, and that the vibration of the ship should not work the contacts loose or permit of the filament being unduly shaken, which action is found considerably to reduce the life of the lamps (Figs. 11, 12, and 13).

Lanterns, and globes have been designed, not only for use on land, but also for ship purposes, and in this respect the electrician has been ably assisted by those who make it their business to provide these appliances. Such appurtenances should be both elegant and durable, and be fixed so that the light is shed downwards on the passenger, rather than hung on a level with his eyes, the most approved plan of lighting being to suspend short brackets with their globes from the ceiling over the centre of the tables, so that they are clear of the passage-ways and wine-glass holders, and distributed so as to give a uniform light, as in Messrs. Siemens Bros. fittings, which have given great satisfaction. The original plan of fixing the electric-lamps inside or attached to the oil-lamps is in great measure discontinued, as an unnecessary complication. In some steamers, where the cabins enter off the saloon, devices such as lanterns of triangular section have been resorted to. By this means the cabins and the saloon are simultaneously lighted, but in this respect each particular shipbuilder or owner has more to say than the electrical engineer. In the engine-room, lanterns with reflectors and wire-cage protectors are largely used, as well as lamps attached by flexible leading wires, to permit of the engineer inspecting different parts of the machinery. In the boiler-rooms the lamps are so fixed as to cast their light directly upon the water-gauge glasses, that the height of the water in the boilers may be readily and easily observed from the stokehole floor.

FIG. 13.



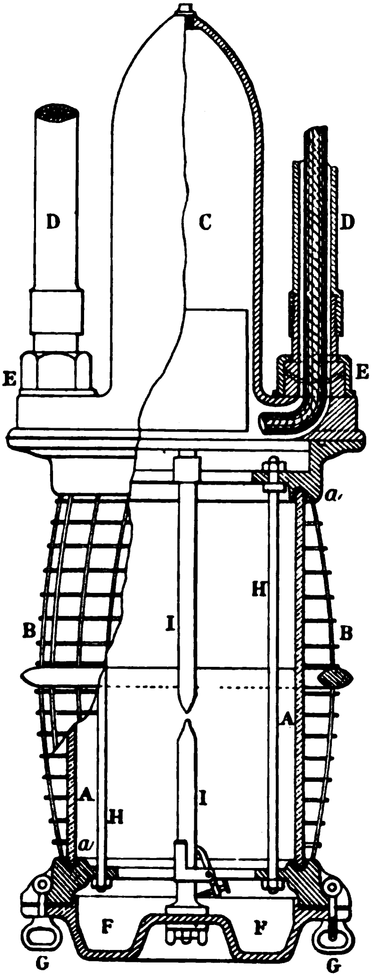
HAROLD'S GLOW-LAMP HOLDER.

S, Wood or Ebonite Screw. T^1 T^2, Brass Terminals. E^1 E^2, Electrodes to attach to the lamp platinum hooks. S W, Spring Wire for keeping the glow-lamp tight and yet easy in position.

ARC LAMPS ON BOARD SHIP.

Arc lamps are seldom used on board passenger-steamers, but they have been found of great use in telegraph steamers, in facilitating paying out, picking up, and repairing operations when conducted at night, and in spotting "mark buoys."

FIG. 14.



Scale ¼.

A, Glass Cylinder enclosing arc lamp 15,000-candle power, made water-tight by indiarubber rings *aa*. B, Copper Wire Cage protecting glass cylinder. C, Dome enclosing mechanism of lamp. D, Copper Conductors from dynamos, enclosed in indiarubber tubing. E, Hydraulic Joints at the ends of conductors. F, Removable Door of lamp for adjustment of carbons. G, Wing-Nuts for ditto. H, Rods connecting top and bottom portions of lamp. I, Carbons 20 millimetres in diameter.

They are largely used in foreign navies, as well as on board British men-of-war. In such cases the arc light is placed inside a revolving holophote case (fixed upon the bridge or well forward), and fitted with a lens and reflector, so as to throw a concentrated beam of light in any desired direction, with the view of inspecting an enemy's position, or of guarding against the attack of torpedo-boats. Such lights are worked from a separate dynamo, and require to be at least 10,000- to 20,000-candle-power. They have been applied successfully by Messrs. Siemens Bros., the Silvertown Company, and by the Anglo-American Brush Company to English men-of-war.

A novel application of the arc light for salvage- and fishing-purposes has been fitted by Messrs. Paterson and Cooper to the s.s. "Tilly," for fishing in Batavian waters. The installation consists of a Gwynne vertical engine, supplied with steam from the ship's main boilers, a Phœnix dynamo, and the submarine lamp of 15,000-candle-power. It is represented in Fig. 14 as fitted with paying-out gear and well-insulated leading wires to reach any required depth. This is the only instance known to the Author of the adaptation of the electric-arc light to submarine purposes, but if the idea is practicable and successful there is ample scope for its application.

Electric-lighting installations on board ship, as well as on land, should be thoroughly well carried out in every particular. Many of the disappointments, failures, and accidents which have occurred have been caused by want of knowledge or carelessness, either on the part of those ordering plant or of those executing orders. The Author recalls to memory Mr. Preece's well-timed caution, in his Paper "On Electrical Conductors," where he says:—"It cannot be too strongly urged that specification without rigid inspection is valueless. . . . Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect."[1]

The Paper is accompanied by numerous illustrations, from which Plates 1, 2, and 3, and the Figs. in the text have been prepared.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxv., p. 74.

Discussion.

Sir J. W. Bazalgette.

Sir J. W. **Bazalgette**, C.B., President, said that the Paper was well worthy of the consideration of the members at the first meeting of their session. It was one of a practical character, on a comparatively novel subject, of great interest, and he was quite sure that the members would desire to give their best thanks to Mr. Jamieson for the careful manner in which he had prepared it, and for the trouble he had taken in travelling from Glasgow to London to be present at the meeting.

Mr. Jamieson.

Mr. A. **Jamieson** desired, before the discussion commenced, to draw the attention of members to the electromotive-force curve of the "Victoria" compound-wound dynamo (Fig. 1). That curve represented the electromotive force of the dynamo when generating currents from 0 to 120 amperes. It was very nearly a horizontal line throughout, and was a remarkable illustration of the rapid improvement that had been made in dynamo machinery within the last two years. How much of this constancy of electromotive force (with varying resistances in circuit) was due to the weight and arrangement of iron in the armature and magnet cores, and how much to the proper proportioning of the size and number of turns of wire in the shunt magnet circuit, to that of the main (or direct) circuit in the armature and magnets?

He wished to mention an experiment tried in connection with the s.s. "Arawa." There were two complete sets of plant, all in line on one sole-plate (Plate 2, Fig. 5, showed one set), either of which was capable of working more than one-half the number of lamps in the ship, the total number being three hundred. When only one hundred and fifty lights or less were required, one set of Ferranti plant was kept in action, but when more than one hundred and fifty or one hundred and sixty were necessary, the second engine was brought up to the same speed as the other, and the two were put into gear. Advantage had therefore to a certain extent been taken of the suggestions given by Dr. Hopkinson in his lecture on "Some points in Electric Lighting," delivered before this Institution, viz., "that two alternate current machines could be used for feeding one set of lamps when the forward and return circuits were common to both machines.

In the case of Siemens' frictional drive, the engine drove, through the intervention of a fly-wheel, and a compressed paper pulley, a dynamo at fifteen hundred revolutions per minute. This arrangement got over the objection of the conservative marine engineer; for he need not see the dynamo revolving at that rate; as the whole apparatus was put into a small corner, and partially covered, so that he was thoroughly satisfied. It had given excellent results wherever adopted. **Mr. Jamieson.**

The rule which he had applied to the size of conductors for electric-lighting in steamships was not a mere arbitrary rule; it was the application of Sir William Thomson's to the particular case of short insulated wires. Mr. T. H. Blakesley, Assoc. M. Inst. C.E., had worked out this question in a Paper read before the Society of Telegraph Engineers.[1] The Author had worked out the same thing some time before in a similar manner for a particular class of leads, and their results agreed very closely. Seeing that not more than 100 amperes were required in any single main lead on board a ship, the sizes of the wires by which a ship could be fitted were few; so that, by means of a rule like that which he had mentioned, a contractor, with the table before him, could at once fit a ship without any trouble in computing formulas.

He had left the question of first cost and maintenance of the electric plant to those who knew more about it than himself, and he hoped that some practical results would be given in the discussion with regard to the length of life of the Swan lamps, the price of installations under different circumstances, and their saving as compared with oil or candles.

Dr. Hopkinson. Dr. JOHN HOPKINSON said that the reason of the success in the compounding of the Victoria dynamo, and some others with which he was acquainted, was that the amount to be corrected by the series coils was small; that was attained by the fact that the field in which the armature revolved was exceedingly intense, and that the resistance of the armature was low. The error to be corrected being small, it could be reduced by the correction to an exceedingly small amount. In machines where the resistance was not so small, and a considerable amount of correction was required, it was not possible to obtain such a degree of accuracy. There was another point with reference to the use of compound dynamos. There could, he thought, be no question that in cases where a single dynamo was connected to the circuit, there was a very great advantage in using a self-regulating compound dynamo. If, however, two compound dynamos were connected to the same circuit, there was an instability in the division of the work between the

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[1] "Journal of the Society of Telegraph Engineers and Electricians," 1884. Vol. xiii., p. 295.

Dr. Hopkinson. two machines, so that one would be overloaded and the other do nothing. The remedy for that was easy. If there were two machines, instead of each machine correcting its own error by its current passing round its own magnets, the current from each machine was taken round and used for exciting the other. The plan, he believed, was an old one, and had first been adopted in the ordinary series machine, some years ago, in experiments made at the South Foreland; but it was worth recalling now, when compound dynamos were in frequent use, and were likely to be connected together with the same circuits. The Author had given what might be called a specification of what he considered the necessary insulation-resistance of dynamos. Dr. Hopkinson thought that such a hard and fast line was not desirable. The smaller the machine the higher should its insulation be. If the size of the machines were doubled, it might fairly be expected that its insulation-resistance—the surfaces being doubled or thereabouts—need not be more than a half, with an equal degree of efficiency and safety. With regard to the size of conductors, there were several points to be taken into consideration. One point was, that the conductor should be such that with its ordinary current it should not get excessively heated. Another was, that the distribution of the potential through the system should be constant; that it should not vary so as to endanger the lamps where it was high, or give an inefficient light where it was low. The third was that energy should not be wasted, and on the other hand, that too great outlay should not be incurred in the first instance in copper. Practically the last was really the consideration which in most cases should regulate the size of conductors. He thought that, in a very large number of cases, conductors were put in smaller than they ought to be, from mere motives of economy. He was sorry that the Author did not go so far as Sir William Thomson's rule. He wished that everybody would go as far as that. It was very difficult to take the exceptional course of insisting on a little more expenditure in prime cost, when everybody was cutting down the cost too fine. Then, with regard to the size of conductors, it was possible that accidental connections might be made between the two conductors which took the electricity to the lamps, and took it away from them, and in that case an excessive current might pass through the conductors. To provide against that, cut-outs, as they were called, had been introduced which, if the current was excessive, would be fused before the wires became too hot. If the conductors were reduced at every branch to their minimum fair limit for the current which they had to carry, then at each branch cut-outs should

Dr. Hopkinson.

be introduced. That involved a certain complication. Sometimes economy would be realized by making the smaller conductors of a larger size, and consequently avoiding the necessity of so many cut-outs. A sufficiently large conductor could be put to a single lamp to carry considerably more than the current for one lamp, enabling the electrician to dispense with a cut-out for each lamp, and to put one in for groups of three or four. That was more a question of cost and convenience than anything else, but he thought that economy would be realized by increasing the size of the smaller conductors, and diminishing the number of cut-outs. Another point referred to by the Author was the relative advantages of two methods of wiring a ship; first, that of having a conductor to take the electricity to the lamps, and an insulated conductor to take the current back from the lamps; and secondly, that of having a single set of insulating conductors using the ship itself as a return. For his own part, he greatly preferred the former method, for this reason: it was not merely a question of having, so to speak, two strings to one's bow in the insulation; it was not merely that if there was a breach of insulation there was likely to be a breach between the copper and ironwork of the ship; but it went further; if such an accident occurred—if the earth insulation of one of the conductors broke down, and there was consequently a contact between the conductor and the body of the ship—if both systems were insulated, the electricians would, by proper arrangements, be aware of the fact that the insulation had given way before any danger or inconvenience occurred, and steps could be taken to remedy the defect. Besides, if there were two systems of conductors, both insulated, it was easy, when the machine was in operation, without interfering with the work in any way, to determine the insulation-resistance of both the positive and negative conductors. It was a great advantage to have it determined from time to time, so that if any defect was beginning to be developed steps might be taken to remedy it before any mischief could arise. For those reasons he felt strongly that, though good work might make a single-conductor system thoroughly satisfactory, still the least defect might always lead to serious damage without giving any warning; whereas in the other case, if the work were not so good, whenever a defect occurred notice was given of it before any mischief arose. With a little watching and attention the whole might be made perfectly secure. As to the use of alternate currents, when he had the honour of lecturing before the Institution, he pointed out that alternate-current machines, even if they were independently driven, had the power of regulating each other;

Dr. Hopkinson. that if they were coupled in parallel circuit they would tend to add their effects, and if in series they would tend to neutralize each other. Since then that point and other points connected with it had been experimentally verified, so that there could be no question about it. The synchronism of two alternate-current machines, when connected together, had been described by Mr. H. Wilde sixteen years ago;[1] but this Paper had been unfortunately overlooked by those interested in the subject. The Author, he thought, did not completely apply that theory to the particular case shown in Fig. 9. There was no need whatever for any clutching of the two machines. The machines themselves, when once started at the same speed, even though driven by independent straps, would control each other and drop into perfect synchronism, marching in step, even though each was making three hundred steps in a second, and with a power of 20 or more HP. The effect of the control in that case would actually be to produce what the Author had shown.

Professor Perry. Professor JOHN PERRY said that the Paper was a very useful one, and he only regretted that it did not contain a little more of the Author's own statistics. In speaking of compound dynamo machines, neither the Author nor Dr. Hopkinson had referred to the name of Mr. Marcel Deprez who really originated the principle of compound winding, and made it possible for a dynamo machine, kept running from a well governed engine at a constant speed, to develop almost exactly the same electromotive force, or to give the same light from every lamp, whether one hundred lamps were burning or only one of a circuit. True, Deprez regulated his dynamo in a different way from the latest compound-winding method, as it was also different from the method of himself and Professor Ayrton; but the methods were all essentially the same in principle, and he regarded the discovery of this principle by Deprez as the greatest discovery since that of the dynamo machine. One of the most important points in the Paper was that relating to the positions of the dynamo and of the engine in the ship. It was possible that mechanical engineers had not got sufficiently accustomed to the idea of gyrostatic action to take account of the pressures on the bearings of rapidly spinning bodies such as dynamo machines. He supposed that it was natural for electrical engineers to consider gyrostatic actions. They were accustomed to think of a magnet as a ship with a great number

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[1] Proceedings of The Literary and Philosophical Society of Manchester, vol. viii., p. 62; and Philosophical Magazine, Fourth Series, vol. xxxvii., p. 54.

Professor Perry.

of compartments, there being in each compartment a rapidly spinning body. Sir William Thomson first drew attention to this matter, and it was very natural for him to do so as he first explained why a top rose, why a stone rose on its longer axis when spun, or why an unboiled or rotten egg would not get up on the table when an attempt was made to spin it, whereas a well-boiled egg would get up. Anyone who had held one of Sir W. Thomson's large gyrostats in his hands, and had tried to turn it, knew that considerable pressure might be produced at the bearings of dynamo-machine armatures. When the dynamo machine was turned about an axis, the armature tried to place its axis of spinning parallel to the axis of turning. Now, from what had been said, some members of the Institution might have come to think that quick-speed engines were a disadvantage in ships. As he rather advocated the use of quick-speed engines for the driving of dynamo machines and other purposes, he and Professor Ayrton had examined the question of the relative pressures on the bearings of, say, the crank-shafts of two engines of the same power, one a quick-speed and the other a slow-speed engine, and they had found that, taking the same ratio between the initial pressure of steam and the mean pressure of steam in the cylinder, to give the same fluctuation in speed, the moment of inertia of the fly-wheel was inversely proportional to the cube of the speed, and therefore the gyrostatic couple, the couple which produced the pressure on the bearings due to any rotation of the ship, was inversely proportional to the square of the speed. The dimensions of fly-wheels which were made to the same drawings but to different scales, were inversely proportional to the fifth power of the moment of inertia, and the result was an inverse proportionality to three-fifths of the power of the speed. Hence the pressure on the bearings of the engines was inversely proportional to one and two-fifths of the power of the speed. Taking into account the fact that in quick-speed engines there was a longer bearing, it might be said roughly that the pressure per square inch on a bearing was inversely proportional to a small power of the speed, which was favourable to a quick-speed engine. But suppose the subject to be looked at from the ordinary point of view of the mechanical engineer. In the first example taken by the Author, of a Siemens armature, the pressure on the bearings was found to be 3·6 lbs. If it were supposed that this dynamo machine was placed in the ship in such a position that it could get an ordinary translational motion of 10 feet amplitude, and taking the sixteen seconds periodicity of swing, it was found that the pressure on each bearing would be 12 lbs.; so that the pressure

Professor Perry. due to the cause generally considered by the engineer was three and a half times as great as the pressure due to the gyrostatic action. Further, he had considered the case of a ship having a swing, which was a simple harmonic motion, and it was well known that occasionally towards the end of a swing there was something very different indeed from the end part of a simple harmonic motion. So the pressure on the bearings might be many times greater than the gyrostatic pressure which had been spoken of. It should be remembered that the gyrostatic action was proportional to the greatest angular velocity of the ship, whereas the second action of which he had spoken, the one well known to engineers, was proportional to the rate at which the motion was altered. With regard to governing, the Author had spoken of 10 per cent. fluctuation in speed as not attainable, and he had stated as an example, that when one hundred lamps were being burned, and ninety-nine lamps were suddenly switched out, and only one lamp was left in, the difference in the speed for an instant was about 25 per cent. No one would be astonished at that. If 99 per cent. of the whole work was suddenly taken off the engine, it would be a most extraordinary stoppage of power, and probably in practice nothing like that sort of stoppage of light could ever occur except as a total stoppage. In any case, he had no doubt that if an electrical engineer would only ask a mechanical engineer for a minimum fluctuation of 10 per cent. in speed when there was, say, 80 per cent. fluctuation of power, he would get it. It was because they had not been in the habit of asking for good governors that electrical engineers had not obtained them hitherto. The electrical governors, sometimes spoken of as very good, appeared to him to be only comparatively good. They all depended on the principle that if there was an electro-magnet, and a certain current passing round that magnet, the magnetic field produced by the magnet was constant. Now it might be advisable to warn inventors that the magnetic properties of iron were hardly known to the writers of books and to electricians who had not made them a special study; and that measuring instruments which seemed excellent hypothetically were often practically very bad. And in regard to the action of strong electro-magnets differing in character from the weak ones used in Ayrton and Perry's Solenoid Ammeter and Voltmeter, they might use the very best of the three best brands of Swedish iron, they might anneal it in a vacuum from such a high temperature as to make them afraid that the shape of the iron would be spoiled, they might take care that no file or other tool touched it afterwards, and if they tested it in a strong electro-

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magnet they would find that the field produced was not always the same for the same current. Let them for example increase the current from 0 to 20 amperes, and then see what the field was. Now beginning with 30 amperes, and coming down to 20, it would be found that the field was not the same. The character of the field depended to some extent on the past history; he wished it did not. That was a defect which would be found in all electric governors of engines, depending upon the action of a strong electro-magnet. As to another matter, the size of the leads, Sir William Thomson's rule led to a little over 3 square inches of copper in the lead per 1,000 amperes of current. Taking, however, the copper at £100 instead of £75 per ton, and 15 per cent. for interest and depreciation, the result was 2 square inches per 1,000 amperes. Mr. Blakesley took 1 square inch for 1,000 amperes, allowing for the cost of the insulation of the leads; but it seemed to Professor Perry that too much stress was laid upon the cost of the leads. Because Sir William Thomson, at the time when transmission of power for long distances was engaging attention, just after he had been discussing the transmission of power from Niagara to New York, based his calculations on what was then all-important, the cost of the copper leads, every electrical engineer now based his calculations on the cost of leads, although they might only be a few feet in length. The much more important consideration for single house and ship lighting was neglected, namely, ought not the light from the lamp to be constant? Given the best governor imaginable, whether electric or whether a mechanical governor, the dynamo machine being double wound, it only aimed at keeping the difference of potential constant at some one place in the system, so that a lamp at that place would be always of exactly the same brightness. But it did not follow that at a certain other place the light would always be of the same brightness. It depended on the number of lights between one place and another, and on the section of the leads. If a number of lights were switched out, there would be a different brightness in a particular lamp from its brightness before the others were switched out. Thus if there were absolutely perfect governing in the dynamo room in the Author's system, and if a room contained, say, fifty lights, fed by cables 200 yards in length from the dynamo room, and if forty-nine were switched out, the remaining lamp must have its potential increased 2·46 volts. Now an alteration of even a fraction of a volt was annoying in a 100-volt lamp, so that an alteration of 2·46 volts was a very

Professor Perry. important matter. The only way in which this could be prevented was by lavishness in the cost of the copper cable, and this part of the total cost of a ship-lighting installation was comparatively small.

Sir J. W. Bazalgette. Sir J. W. Bazalgette, C.B., President, said that the Author thought the discussion upon his Paper might well embrace observations on the following points:—1. Direct-driving engines *versus* other methods. 2. Governors, electric and mechanical. 3. Low- *versus* high-speed dynamos on board ship, with their relative efficiencies, curves, weights, and cost. 4. Alternate- *versus* direct-current dynamos. 5. The two systems of fitting leading-wires on board ship. 6. The sizes of wires and their necessary insulation-resistance. 7. Fusible cut-outs and lamp-fittings. 8. The first cost, life, and maintenance of the different kinds of plants, or of the dynamo machines tried on board ships. 9. Search-lights; their uses, first cost, and maintenance.

Mr. Preece. Mr. W. H. Preece said he was not aware that it was customary for the Author of a Paper to lay down points to which the discussion should be directed; it was rather for those who had heard or read the Paper to form their own opinion as to what should be taken up for discussion. There were, he thought, two satisfactory points in the Paper, to which attention should be paid; the first was, that there was at any rate one branch of electric lighting that had turned out to be an unqualified success. The Author, and those who had introduced electric lighting on board ship, had certainly brought to the traveller a comfort that none but those who had been down to the sea in ships could thoroughly comprehend. It had been his lot to have recently experienced the great discomfort of a journey across the Atlantic. He had travelled in the rear of a severe cyclone, and for two days the ship tumbled and tossed and rolled in a way that was uncomfortable, even to a good sailor. It was in the middle of the night, however, when he turned a little switch and was able to throw a flood of light into his cabin, that he appreciated the comfort of the electric light. That was what had happened to him and to many others in crossing the Atlantic. They enjoyed the comforts of daylight, and felt that the tediousness and discomfort of the passage were greatly reduced. Mr. Preece's first experience of electric lighting on board ship was in laying a cable across the Mediterranean, from Marseilles to Algiers. No one who had seen the facility that electric lighting afforded for those difficult operations connected with the laying and picking up of cables, would ever

Mr. Preece.

undertake the operation of submerging a cable without the adjunct of that marvellous assistant, and he was pleased to be able to say that there was not a single cable-ship now arriving in England that was not being completely fitted with electric lighting. A fleet of thirty-one ships was now maintained in different parts of the globe for the express purpose of looking after submarine cables, and the ships were all fitted with that contrivance. The ferry-boats across the Hudson River in connection with the Pennsylvania Railroad were all fitted with electric lights. He had also crossed from Boston to New York, taking the water at the Fall River, and journeying by the steamer "Bristol." In all the state cabins, saloons, and passages, the Edison light was constantly burning, and the arrangements were of a perfect character. A special engine-room was apportioned for this purpose; there was duplicate plant of engines and dynamos, and two hundred and fifty 16-candle lamps were scattered over the ship. The "Aurania" was fitted up by Messrs. Siemens, and it might be reasonably anticipated that a ship fitted by so eminent a firm would have all the appliances that science and skill could furnish. There were six hundred lamps worked by two three-hundred-light self-regulating dynamo machines of Siemens patent, each driven by an 8 (nominal) HP. (Caledonia) steam-engine, by means of ropes and grooved pulleys; and two 60-light dynamos of similar construction, each driven by a 4 (nominal) HP. Tangye vertical-engine. Those engines and dynamos were used specially for the engine-room and the stoke-hole, and for what were called police-lights. They started from the moment the ship left New York, and continued running until her arrival at Liverpool, and during the whole of that time not a single flicker was observed; the lights were absolutely and perfectly steady, and at all times and seasons every part of the ship was thoroughly illuminated. There were, however, two or three defects in the saloon arrangements, which were due to bad joints. The Author had pointed out the modes by which the electric currents could be distributed throughout a ship; of course, in all these cases, the ship was really lighted by the coal burnt in the furnace; the energy developed in the furnace was, by means of the engines and of the dynamo, converted into that form of energy called electric currents, and when those currents passed through a thin carbon filament they developed the other form of energy called light. The currents were distributed either by the one-wire system described in the Paper, Mr. Preece. where the return was the shell of the ship, or they might be distributed by means of two wires—a method justly praised by Dr. Hopkinson. Again, they might be distributed by three wires, according to the mode employed by Mr. Edison in America, but also invented by Dr. Hopkinson for other purposes in England. It was essential in an installation of electric lighting, to have the currents so distributed as to have an equal pressure all over. On board ship, and in a private house, a continued service was required, so that, in case of accident or disturbance of any kind, by turning on a little switch an energy could be elicited that would flood the whole cabin or room with light. Bad joints and leakage were a frequent source of trouble on board ship. Even on board the "Aurania," when the ship rolled from side to side, one chandelier after another went out. The result was due to the ignorance, not, of course, of those who ordered the work, but of those who carried it out. It was a great satisfaction to know that electric lighting was improving, and that it was favourably received by the members of the Institution.

Mr. Swan. Mr. JOSEPH W. SWAN remarked that, looking at the incandescent lamp from a theoretical point of view, it was difficult to understand why as large a return of light for a given expenditure of electric energy should not be obtained from the white-hot filament as from the glowing crater of an arc lamp. In both cases the source of light was the same—electrically heated carbon. From the circumstance that the incandescent filament was not cooled by air currents, and the carbon of the arc lamp was so cooled, even a larger return of light from the filament might be anticipated; and this anticipation was not less warranted by the fact that the whole mass of the filament was uniformly heated, and that its entire surface emitted light, while the pencil of the arc light was unequally heated, and only a small part of its surface, to the degree of incandescence. Experiment confirmed this deduction. He had measured the light of an incandescent lamp when it was giving at the rate of close upon 2,000 candles per electrical HP., or a candle for less than ½ watt. That was a larger return for energy expended than was usually obtained from a small arc; but it was all he could do to take the readings before the filament gave way under the disruptive action which attended this exceedingly high temperature. The practical lesson of this experiment was that, if the carbon filament of an incandescent lamp were heated to an excessive degree it would not last. On the other hand, he had had reported to him the case of an electric-light installation in which a considerable number of the lamps had been in action during five thousand eight hundred hours, and they were still in use. He did not know the energy consumed for the light given in this case, but he felt pretty sure the lamps had not been highly heated. Probably as much as 4 or 5 watts instead of ½ watt had been expended for every candle-light obtained. The question at what point between these extremes the cost of maintaining a certain required quantity of light would be least, was undoubtedly one of the greatest importance in relation to the economy of electric lighting by incandescent lamps. It was one which involved many varying conditions, and it had not yet been answered. To answer it completely, a number of carefully performed experiments were required, with numerous lamps of different kinds, lighted by currents of different kinds and strengths, constantly maintained for a considerable length of time. Experiments of the required thoroughness had never been made, and he doubted if really much more was known than that when the rate of 3 watts per candle had been attained, the lamp was living a fast life which would not last, and that below 4 watts per candle, and the lamp was not constitutionally bad, a green old age might be predicted for it. This he knew perfectly well was far from being a precise statement, but in the present state of knowledge it would not be safe to make it more precise. The question, however, was being considered in relation to ship lighting, and there it was evident what ought to be done. The two chief elements in the question were, the cost of lamps and the cost of power. Where power cost little it was more economical and convenient to take a small return of light for power expended, than to exact a large return at the expense of more frequent lamp renewals. This was the case in ship lighting; for whether an amount of light equivalent to 200 candles per electrical HP., or only 100 candles, was obtained, did not greatly affect the cost of light on board a steam-ship where 1 HP. was developed by 2 lbs. of coal. Suppose, for example, that two hundred lamps were installed on a certain ship, and that all were lighted during an average of five hours a day, winter and summer—a length of time sufficiently in excess of the actual time to compensate for the few lamps lighted during additional hours. Assuming the indicated HP. to be developed by 2 lbs. of coal, and that there was a loss of 33 per cent. in transforming the mechanical energy into its electrical equivalent in the lamps, it would result that from 3 lbs. of coal 100-candle light would be obtained during one hour in one case and 200-candle light in the other; or, to Mr. Swan.

Mr. Swan. sum up the time and the coal so as to ascertain the cost in larger figures:—Every ten lamps expended 746 watts, and required 3 lbs. of coal per hour; 60 lbs. per hour for two hundred lamps, and 300 lbs. for the five hours a day, or nearly 1 ton of coal per week. Then, to get the same amount of light with such a low temperature of filament that only 100 candles per 2 HP. resulted, just twice this quantity of coal would be consumed, namely, 2 tons per week instead of 1 ton—a quantity so small that the breakage of a few lamps every week would more than equal its value. Or, supposing the average life in one case to be five hundred hours, and in the other five thousand, it would certainly be more economical to burn the larger quantity of coal and to have fewer lamps to renew. What the precise result would be in these two cases could not, as he had said, be stated with minute accuracy, for a good deal depended on the cost and quality of the lamps. But this at least was evident:—the total cost of coal consumed was so small in either case, that if any considerable increase of longevity in the lamps, from, say, hundreds to thousands of hours, followed from the lower rate of light efficiency, and he did not doubt that would be the result, it would, on the whole, be better to burn the extra ton of coal per week in order to reduce the cost and trouble attending the renewal of broken lamps. He therefore thought that for lighting steamships it was advisable to maintain the lamps at a moderate temperature.

With regard to the two modes of distribution described by the Author, he concurred in Dr. Hopkinson's view that the two-wire system was the safest, and therefore the best. It was impossible to be too careful to ensure the maintenance of good insulation in the conductors, and there could be no question that the two-wire system contributed to that condition. Not only the wires, but the dynamo and the lamp-fittings should all be insulated from the skin of the ship. Where wires passed through iron partitions, the holes should be bushed with wood or other insulating material. He passed from these cardinal points to notice two minor details, namely, switches and fusible bridges, or cut-outs. There were numberless designs for these small but indispensable appliances, and both in design and construction he thought many of them were susceptible of improvement. A switch for a ship should be strongly made, and so simple and sure in action that it could not by any possibility get out of order. In his opinion there ought not to be any combustible material about it. The base to which the metallic fittings of the switch were attached should be earthenware, or

Mr. Swan. some material as incombustible as earthenware. He said the same of fusible bridges, which should be fixed at every junction of a branch with a trunk wire. To render these the complete protectors they were intended to be, they should be both well designed and carefully fitted. Lead wires should never be used, unless the ends of the copper branch wire into which the piece of lead wire was inserted were soldered to the ends of the lead wire. If this could not be conveniently done, and he thought possibly it could not, then lead must not be used, for it was so soft, and so prone to oxidation, that it was impossible to make, or at least to preserve, good contacts between it and the ends of the wire by means of nuts and washers, however firmly they might be screwed "home" at first. A much better metal for the purpose was tin. It was more fusible than lead, less readily tarnished, had almost as high a specific resistance, and was sufficiently hard to enable a good contact to be made by means of screw connections. Tin could be drawn into excellent wire for this purpose, or pieces of a proper size and form, with enlarged ends or lugs, could be stamped out from sheets of pure tin. These were small details, but they had an important bearing on the safety, the efficiency, and the permanence of a system of electric lighting on board ship.

Mr. Mance. Mr. H. C. MANCE, C.I.E., said the Author had stated that one hundred and fifty ships had been fitted with the electric light. It would be interesting to learn if the electric light was still used on all these ships, or, if not, the reason of its discontinuance. No doubt a great many blunders had been made in some of the early installations, and if they were ascertained they might be avoided in future. He could testify to the ease with which the electric light was kept in order on board ships. He was frequently on board the "Patrick Stewart" Government telegraph steamer, stationed in the Persian Gulf, which had been fitted by Messrs. Siemens, about six years ago, with a continuous-current dynamo machine, suitable for a 1,000-candle arc lamp. The dynamo stood on a small platform just over the entrance of the shaft tunnel, and the arc light was on the bridge. It had not been moved for six years. It was not often used, but it was always ready, and beyond the expense of the carbon, it had not cost a penny for maintenance. It was occasionally employed when the cable work was prolonged into the night to get the final splice overboard, and in that way it was of great assistance. When he returned to India he should take with

Mr. Mance. him the necessary appliances to fit up incandescent lamps in the cable-tanks.

As the question of joints had been mentioned, he might refer to a very small joint used in the Persian Gulf Telegraph Department, which might, he thought, be found of advantage to those who were entrusted with installations at home. He referred to joints above water. They were small india-rubber joints, which had been sent out for their india-rubber cable in small air-tight cases, so that one or two could be used as required. The copper conductor was first soldered, and the dielectric pared down to a taper on both sides. The jointing material consisted of a strip of pure india-rubber, a separator, which was very adhesive, and a red jacket. These strips were applied in succession, and the joint could be made in a few minutes. He had, as a temporary measure, put them down in 40 fathoms of water, and he had never found them give way. They were generally used to connect leads in cable boxes in the harbour, where the water rose within 6 inches of the cable ends. They had given no trouble, and he had found them very serviceable. The cut-outs mentioned by the Author were no doubt correct in principle; but he thought that mechanically they were not exactly suitable for adoption on board ship. Those who were aware of the amount of cleaning and wetting that went on on board ship would know how important it was that the cut-outs should be safe from meddling and be dry, so as to avoid any surface leakage. He had occasionally used cut-outs to protect the cables from the effects of lightning. When unprotected, the delicate platinum spirals were easily broken, but they could be preserved by enclosing them. A cut-out should be dry, but at the same time easily visible. He had recently been shown the drawings of one which was protected by a little glass, so that it could be seen if any damage had occurred. It was contained in a piece of ebonite 2 inches long and 1 inch square, so that it would not interfere with the running of the wires along the ship's side. He presumed that the Author meant, referring to insulation, 10 megohms per knot. Beginning with that it would be nearly certain to come down to less than 1 megohm per knot in the course of a year or two. The system of embedding in a grooved paraffined board was no doubt excellent, but it was not always practicable. By applying a serving of tape with india-rubber solution, the gutta-percha leads lasted three times as long. He had great trouble at one time with leads for testing purposes, in which

Mr. Mance. he required greater insulation than would be needed for lighting, and he found that the addition of the tape gave excellent results. With 10 megohms per knot it was evidently intended to have a thin dielectric; there was therefore the more reason for protecting it thoroughly, so as to prevent any mechanical injury. He had tried many things, and he thought that a tape immersed in a mixture of white lead and tallow, which had been boiled carefully, formed an excellent and cheap perservative. He was surprised that nothing had been said about storage batteries. Was it to be understood after all that had been written on the subject that storage batteries were not of the slightest consequence? He was inclined to think that, at any rate for small installations, they would lead to an enormous extension of electric lighting. Of course, what was wanted was a simple, cheap, durable, and efficient storage cell.

Mr. Wynne. Mr. Frank Wynne referred to the statement in the Paper that the expense of the maintenance of electric lighting was not much in excess of the older methods of illumination. That was a point upon which it was very difficult to get satisfactory information. The estimates received of the cost of the earlier methods varied from 100 to 150 per cent. Those variations not only applied to ship lighting, but also to railway lighting. He had hoped that the Author would have been able to give some trustworthy details on the subject. With regard to driving by iron gearing, he might mention that in the case of a Mexican ship fitted with machines, it was found to answer very well. No doubt, however, it was a severe trial to a machine to be driven by cast-iron gearing, to say nothing of the noise; and when there was an excellent system like that introduced by Messrs. Siemens Bros., known as the Raworth gearing, he did not know why it was not more generally adopted. It had been suggested, and he thought that the suggestion was a very practical one, that the driving-wheel should be the soft surface, and not the driven wheel. That seemed very rational, because otherwise there was a danger of a facet being cut upon the driven wheel. Mr. Wynne was in favour of direct-driving machines. That was the best method for quick speed, but the company with which he was connected had systematically adopted low-speed dynamos, as getting over all the difficulties connected with shafting and belting. He had expected to hear more as to what had been done with driving by ropes, and he hoped that the Author would say something on the subject. He believed that low-speed dynamos were unquestion-

Mr. Wynne. ably the best. Attention had been directed to the characteristic curve, nearly straight, of the Victoria dynamo (Fig. 1). It might have been made perfectly straight. The electromotive force was permitted to drop slightly as the current diminished, both to allow for the decrease of loss in the leads, and also for any momentary acceleration of speed in the engine where suddenly relieved of a large portion of its load.

Mr. Farquharson. Mr. J. Farquharson observed that the Author of the Paper had made some reference to what was being done on board men-of-war; and as he knew more about those ships than about merchantmen, he might be allowed to state that the Author was rather in advance of the actual state of the case in saying that no man-of-war now left the builder's hands without being lighted electrically. There were but three fighting ships in England so lighted. The first lighted by the incandescent system was the Brazilian ironclad "Riachuelo," and since then two other ships in the navy had been fitted, the "Polyphemus" and the "Colossus." A great many transports and troop-ships had been lighted, and he was able to give some particulars of the results obtained in one or two of them. During the last year and a half five large Indian troop-ships, the "Malabar," "Crocodile," "Serapis," "Jumna," and "Euphrates," had been lighted, and the Imperial troop-ship "Orontes." The five large troop-ships had an installation of about four hundred lamps each, and he had some particulars of the cost of two of them, which had been carefully prepared with a view of showing how the cost compared with that of ordinary lighting. Before reading the statement, he might remind the members that it ought not to be assumed that the cost of lighting ships in the Royal Navy by the ordinary system was fairly comparable with the cost of lighting other ships. No mineral oil, for example, was allowed in ships of the Royal Navy, and the colza and olive oil used in them was more costly, so that the comparison would not be the same as that with private ships.

DETAILS of the COST of LIGHTING H.M. INDIAN TROOPSHIP "CROCODILE," for NINETY DAYS, by the OLD and NEW SYSTEMS, viz. CANDLES and OIL, and ELECTRICITY by INCANDESCENT LAMPS.

The number of lamps by each system was about the same. The actual number of incandescent lamps was four hundred and thirty-eight. They were of two sizes, viz. 10-candle power three hundred and seven, and 16-candle power one hundred and thirty-one. It would be seen by the details of cost that the bulk of the ordinary lamps were candles, and the proportion of light would therefore be electrically greater as 10 to 1 or thereabout.

Mr. Farquharson.

Details of Expenditure.

New System.—Incandescent Lamps. Details of Material.	£.	s.	d.
Coals, 112½ tons at 15s. per ton	84	7	6
Cotton waste, 90 lbs. at 27s. per cwt.	1	1	8
Oil (Mineral), 180 gallons at 1s. 2d. per gallon . .	10	10	0
„ (Olive), 23 gallons at 3s. per gallon	3	9	0
Lamps replaced, 35 at 3s. 6d. each	6	2	6
Lamp globes, 15 at 3s. each .	2	5	0
Fusible wire plugs, at ¼d. .	0	1	8
Depreciation on plant, at 2½ per cent.	12	0	0
Total. . .	119	17	4

Old System.—Candles and Oil. Details of Material.	£.	s.	d.
Candles, Stearine, 250 lbs. at 32s. 4d. per 50 lbs. .	8	1	8
„ Police lamps, 1,300 lbs. at 32s. 4d. per 50 lbs.	42	0	8
„ Fighting lamps, 1,750 lbs. at 34s. per 50 lbs.	59	10	0
„ Signal, 1,430 lbs. at 34s. per 50 lbs. . .	48	12	0
Oil, Colza, 493 gallons at 2s. 3d. per gallon . .	55	9	3
Wicks, Cotton, 160 at 1½d. per doz.	0	1	10½
Cotton balls, 8 lbs. at 8½d. each	0	5	8
Chimneys	0	4	0
Depreciation of plant, at 2½ per cent.	3	14	0
	217	19	1½
Abate value of cases returned	4	14	0
	213	5	1½
Total cost of new system .	119	17	4
Difference in favour of Electricity . . .	93	7	9½
Or £377 per annum.			

The labour on the two systems was practically the same.

The statement took no account of labour by the old or by the new system, the fact being that no additional labour was allowed. Two engine-room officers were told off to attend to the dynamos and the incandescent lamps, and since as many lamp-trimmers would be employed on the old system, the cost for labour would be approximately the same.

He had received the subjoined return relative to the electric lighting of H.M.S. "Malabar," from which it would be seen that it was possible to make lamps that would last more than six thousand hours.

Mr. Farquharson.

NUMBER of HOURS ELECTRIC LAMPS have been BURNING in the different CIRCUITS on H.M.S. "MALABAR," and the NUMBER of LAMPS which FAILED in each from various CAUSES, from AUGUST 6th, 1883, to OCTOBER 31st, 1884.

Circuits.	Number of Lamps in Circuit.	Number of Hours.	Lamps Broken from the undermentioned Causes.					Remarks.
			Plaster Soft.	Fibre Broken.	Accidental.	Collapsed.	Total.	
Saloon deck aft, day . .	54	1,736	1	6	2	2	11	The average life of the 130 lamps which failed from breaking of fibre, or collapsing, was 3,799 hours each: the shortest life being 638½ hours for 8 yard-arm lamps of 32 C. P.
" " " police . . .	19	3,950¼	..	4 and 1 (32 C. P.)	1	..	6	
" " forward, day .	30	1,030½	1	3	..	..	4	
" " " police .	27	3,912	4	23	9	..	36	
Main deck aft, day . . .	28	1,769½	1	..	..	..	1	
" " " police . .	6	4,506	..	4	1	..	5	
" " forward, day . .	86	901	65	8	14	1	88	
" " " police .	17	3,953	9	5	3	..	17	
Lower deck aft, day . . .	25	1,733	..	1	1	..	2	
" " " police . .	6	5,763	..	3	..	..	3	
" " forward, day . .	34	791¼	17	13	3	1	34	
" " " police .	5	3,820	4	4	1	..	9	
Engine-room	37	6,322	16	29	19	10 and 2 (32 C. P.)	76	
Store rooms	10	5,793¼	1	2	1	..	4	
Starboard yard-arm . . .	8 of 32 C.P.	638½	..	7 (32 C. P.)	2 (32 C. P.)	1 (32 C. P.)	10	
Port yard-arm	8 of 32 C.P.	316½	..	..	6 (32 C. P.)	..	6	
Broken in lamp-room . .	..	..	..	..	4	..	4	
Total . . .	400	..	119	113	67	17	316	

He had also another return which he thought would be interesting to the members. Mr. Farquharson.

Number of Incandescent lamps worn out from various causes, and replaced in H.M. Indian Troop-ship "Malabar" between the 6th August, 1883, and 16th February, 1884, viz., one hundred and eighty-three days; and the number of hours each lamp had been burning: the total number of lamps in the installation being three hundred and eighty-four.

Number of Hours Burnt.	Cause of Failure.				
	Plaster Softened.	Fibre Broken.	Collapsed.	Accidental.	Total.
488	12	11	1	2	26
543	40	2	1	5	48
613	1	1	..	..	2
995	..	..	..	1	1
1,019	1	3	2	2	8
1,042	1	..	..	..	1
2,193	1	3	..	1	5
2,226	6	2	..	3	11
2,254	4	13	..	6	23
2,259	..	..	..	1	1
2,431	..	..	..	1	1
2,994	..	1	..	..	1
3,558	1	1	..	..	2
3,698	8	9	6	11	34
Total . .	75	46	10	33	164

Summary—	Failure of fibre	46	Total from actual use, 56.
	Collapsed	10	
	Accidental	33	
	Softening of plaster . . .	75	

The mean life of the fifty-six lamps broken in actual use was two thousand and sixty-three hours. The cost of the lamps exclusive of the seventy-five which failed from a defect in manufacture, which defect had since been remedied, viz., eighty-nine at 5*s.* (being the increased price now charged for them), was £22 5*s.*, or £44 10*s.* for the whole year on an installation of three hundred and eighty-four lamps.

Mr. Farquharson. An allowance had been made of 2½ per cent. for deterioration of plant by both systems of lighting. The choice of position for dynamos, so far as ships of the Royal Navy were concerned, was limited. There were no unappropriated spaces in a man-of-war, and the question of lighting had not been considered when the ships were built. There was a choice of two or three places, none of them being very good; but it had never been necessary to put the dynamos athwart ships, and so far, with very few exceptions, there had been very little injury to the dynamo from gyrostatic action. He did not know what the Author's object was in his statement with regard to the selection of dynamos; but if intended for the guidance of those who knew nothing about them, the better way would be to specify distinctly the work to be done, and the conditions under which it was to be done, with the limits of weight and size. The Author had stated that dynamos underwent an insulation test of 10,000 ohms per volt generated. It was certainly not expected to get anything of that kind in the ships of the Navy. After a dynamo had been running for some hours in the vapour of steam, and in a generally moist condition, it was considered satisfactory if no blue sparks could be got in the dark by taking a wire from one of the brushes to the frame of the machine, the frame of the machine being connected with the ship. So far there had been no failure in a single instance. With reference to the speed of the dynamo in the navy, gearing of every description was avoided, all the dynamos being driven direct. In former years some of the dynamos were driven by gearing, but the practice had been entirely discontinued. It was now considered that the proper speed of a dynamo was that which would secure a lasting and economical engine, and with that view it was thought that for dynamos which might be expected to have a load of from 16 to 18 HP. four hundred revolutions was a good speed, and there was no difficulty in obtaining good engines to work at that speed. The result, judged by the amount of work done by the power absorbed, would be the same with that or a higher number of revolutions per minute, but the cost was necessarily more; and it might be taken that the cost of a low-speed dynamo was increased about 40 per cent. Comparing it with a dynamo running at one thousand revolutions doing the same work, 40 per cent. more would have to be paid.

As to the governing of an engine, no difficulty had been experienced. He was not aware of the failure of a single lamp from extra stress put upon it through the increased speed when the load was lightened. It had been stipulated that the system should be capable of allowing 90 per cent. of the lamps being turned out without any extra strain being put on the remainder. That was one of the tests applied to ascertain whether the stipulation in the contract had been kept, and there had been no difficulty in accomplishing it. The speed of the engine, when all, or nearly all, the lights were taken off, was somewhat increased, but well within the limit given by the Author. The engines were governed sufficiently at that low speed so as not to exceed twenty-five revolutions more for a moment than with the whole load. He thought, therefore, that electric governors were unnecessary. In the Navy, ships were wired on the double system, with one exception, but he knew no good reason why it should be adopted. Electricians were asked to believe, without any reason, that it was easier in the one case to connect the wire with the skin of the ship than in the other to connect the two wires. He had never been able to learn that the work by the one system was more liable to derangement than by the other. The Admiralty had a ship wired on the three-wire system, and it had turned out to be the worst of all. He might mention what happened in practice. After coaling, the hose was turned on, and leakage took place in the casings, and water lodged in the grooves, which soon destroyed the dielectric, forming, as the Author had described, sub-chloride of copper, and soon corroding the wire. Surely two wires were more liable to injury of that kind than one wire. Government had spared neither money nor time in trying to avoid that leakage, but had not entirely succeeded in a single instance. They were now about to do something in the hope of preventing it, namely, to sink the grooves one and a half time the diameter of the wire, completely filling in the groove with a composition of 80 parts of common putty, and 20 of white lead. That did not shrink or crack much, and it would at any rate have the effect of preventing the lodgment of water, whether with the one-wire or the two-wire system. If by any means the water could be kept out, more would yet be accomplished. With reference to fusible cut-outs, he was glad to hear that Mr. Swan advocated tin wires; but the Author appeared to be under the impression that cut-outs were needed for a purpose not at all contemplated in the Navy, namely, the saving of the lamps. By a properly-balanced compound-wound machine, no trouble was experienced in that respect. In the event of a nail being driven in to hang the cook's ladle upon, unless there was a cut-out in the branch the wire would be heated, which

Mr. Farquharson.

Mr. Farquharson. might ignite the casing. The cut-outs were for the purpose of opening a circuit in case of its being shortened. A cut-out was put in every main, in every submain, and in every branch to prevent extra heat and ignition from an accidental cause. He should like to know from the Author whether he should expect that lamps burning with small currents in a high state of incandescence would last relatively as long as those burned in a lower state of incandescence. He had had very little experience with it, but he believed that the nominal candle-power in the ships of the Navy was well maintained.

Mr. Mair. Mr. J. G. Mair asked Mr. Farquharson what type of governor gave such a remarkable result, as to allow the shutting-off of 90 per cent. of the lighting with so small a variation of speed?

Mr. Farquharson. Mr. Farquharson said it was not the question of a governor, but of a dynamo and governor. The engine generally used was a Brotherhood; it had done good service and borne a great deal of hard wear. In the "Himalaya," the dynamo and engine had been running almost constantly for two years, and had cost scarcely anything. The dynamos were Siemens alternating, the only case they had of alternating dynamos. The men-of-war were peculiarly situated as to the kind of dynamo used, because the dynamos were required to do two things, to be able to give a search light of 25,000 candles, and to light a certain number of incandescent lamps when not wanted for that purpose. In all the fighting-ships using the search-lights, there were direct-current dynamos. The dynamos in the "Himalaya" had an exciter, which was of the Siemens S.D. type. It had been running constantly for two years, and had not had any repairs done to the commutator, which might be considered very good wear.

Mr. Siemens. Mr. Alexander Siemens wished to say a few words as to the curve of the compound machine (Fig. 1). It was not a good specimen of a self-regulating machine, no account having been taken of the resistance of the leads. To make this evident, let it be supposed that a current of 100 amperes had to traverse leads, having the resistance of $\frac{1}{10}$ ohm before reaching the lamps. In this case the difference of potential at the terminals of the machine must be 10 volts greater than the difference of potential at the terminals of the lamps. Again, if a current of only 1 ampere was to traverse the same leads, the difference of potential at the terminals of the machine need only be $\frac{1}{10}$ volt greater than at the lamps. A good self-regulating machine should, therefore, give a greater electromotive force when the current increased, the ratio of the increase depending on the resistance of the leads and the maximum current. Mr. Siemens.

With reference to the lighting of the "Aurania," Mr. Preece had complained first, that the pressure of the mains was not equal in all parts of the ship. To a certain extent that was true on the single-wire system. The lamps nearer the machine would have a little less resistance in circuit than those further off; but seeing that the resistance of the main was so small that difference of potential could be neglected. But had Mr. Preece taken into account that unavoidably the lamps were not absolutely equal? Lamps of 20-candle power of nominally 100 volts would require from 98 to 102 volts, a greater difference than that caused by the resistance of the wires, so that when lamps burnt a little less brightly in one part of the ship than in another, it was probably more the fault of the steward than of anybody else. He was sorry Mr. Preece had complained of the joints, and he would take care to have the matter looked into. The chandeliers in the saloon had not been supplied by Messrs. Siemens Bros., and additional lights had been put up by the owners since the installation had been handed over to them.

He thought the Paper, and a good deal of the discussion, had been rather too theoretical. The Author had begun with a short statement of the advantages of electric lighting on board ships, but he had left out the greatest advantage: that it was now possible, for the first time, for marine-engineers to see the engines working; and they appreciated this, as proved by the lights on board the "Aurania" having been at work in the engine-room from the time of the ship's leaving Liverpool until her arrival at New York. With reference to the requirements of dynamos and steam-engines for a ship's installation, the Author had stated the theoretical requirements, but not the practical ones, viz. that the dynamos and steam-engines should both be constructed for rough usage, and should be capable of being easily repaired even at sea, by ship's engineers, and that above all they should be amply powerful for their work. A dynamo which was supplied for two hundred lamps regularly, ought to be able at a stretch to light at least two hundred and twenty without being damaged in any way, and the Author and other engineers would confer a great benefit on electric lighting if they rigorously required contractors to supply large engines and large dynamos. He thought it would be unwise to give up putting a fuse to every lamp; if a fuse were only put to a group of lamps, and an accident happened to one lamp, the whole group would go out, and the

Mr. Siemens. engineer would have to hunt over twelve circuits instead of over one to find out the defect. That was also a practical consideration. Reference had been made to the disadvantage of the single-wire system. One of those disadvantages was stated to be, that if salt water got in chloride of copper would be formed, and the lead destroyed, but he begged to submit that that applied as much to the double-wire system, because no dynamo-machine was ever so completely insulated from the ship that there was no leakage. Mr. Farquharson had pointed out how close together the two wires necessarily were, because there was so little head room, and many other things had to be accommodated. In the case of Her Majesty's ships, and sometimes in the case of ordinary ships, Mr. Farquharson's remarks, that in the single-wire system the wire was near the skin of the ship, would be applicable; but in general it was not, as the wire was on the average 18 inches from the skin of the ship. In a passenger steamer the iron beams were covered with wood; there were panels of wood everywhere, and if any one had injured the insulation of the single main he would have some difficulty in finding the skin of the ship to make a short circuit. In every ship, when it was wanted to make the connection from the lamp to the ship's skin, a considerable distance had to be traversed. He therefore thought that the danger to the single-wire system was entirely theoretical, and that that system was much safer than the double-wire method, where the two wires being closer together could easily be short circuited. Then there was not half the resistance in the single-wire system, because the skin of the ship being of very large extent had virtually no resistance. That meant that if in the one case 10 per cent. of the power was lost, in the other it would be only 5 per cent., and from a scientific point of view all waste ought to be avoided. Another point, not mentioned in the Paper, was the desirability of working the small auxiliary motors on board ship by means of electricity, as there was much trouble with the steam-pipes which led from the boilers to the steam-engines. This would be entirely avoided if their place was taken by the leads to the electrical machines.

Mr. Hedges. Mr. KILLINGWORTH W. HEDGES had recently examined the action of the electric-lighting machinery on board ship, during a voyage to New York and back, which he had made in two steamships of the same line. Each was fitted with apparatus, supposed to have all the most recent improvements. One of them had an alternating-current machine with an exciter on the same shaft, and the other a compound-wound machine. The alternating-current machine gave considerable trouble, but the compound-wound was more satisfactory. During both the outward and homeward trips the lights were worked perfectly, and there was no breakdown nor hitch. He made careful inquiries as to how they behaved on former voyages. The drawback of the alternating-current machines seemed to be chiefly due to the large size of the armature. When there was any play in the bearings, the armature had a tendency to touch one side or the other, and although probably actual contact was hardly made, some of the coils were burnt. He did not think that the plan of putting an exciter and the dynamo on the same shaft was to be recommended for ship-work. It appeared that the power expended was so much greater at one end of the shaft than at the other, that there must be an unequal wear of the bearings, and consequently a tendency in the shaft to get out of line and throw the armature over. The machine was placed in the ship in the manner advocated by the Author, fore and aft, but the compound-wound machine was put across the ship. Another fault common to both machines was the deficiency of the lubricating arrangements. As the machines were placed on board they had the ordinary oil-cups and oil-holes in the centre. When the ship heeled over the oil could not get to the top part of the bearings, and there was a difficulty in keeping them lubricated, especially if there was a wind on one side maintaining the ship at an angle for some time; so that other oil-holes had to be drilled. A simple remedy would be to have a wick underneath, and to put the oil in a cup, something like what was done in the case of railway axles, so that the oil would be sucked up and spread over the shaft equally. The governors were not good, and were not in action, although the engines were fitted with what were considered very efficient mechanical governors. That seemed to be not so much the fault of the governors as of the way in which they were driven, namely, by a belt which was difficult to keep in order on board ship; the consequence was that they were so unreliable, that it was thought better to keep a man on watch constantly, to turn down the steam in the event of the engine attaining too high a speed. The dynamos were driven by rope-gear which seemed to work well. That also gave trouble at first, but the principal difficulty of keeping it dry was overcome by coating it with black lead and tallow. Rope-gearing ought to be boxed in, as there had been a bad accident on the previous voyage from a man getting entangled by the rope. No matter what driving-gear was employed, he thought that it was better for all ships to have direct-acting engines for

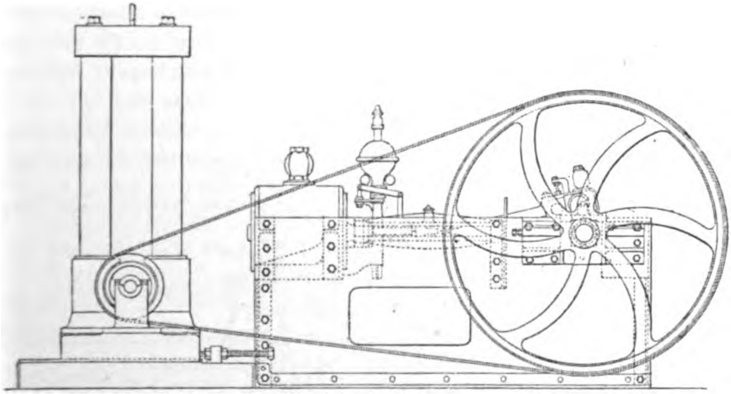
Mr. Hedges.

Mr. Hedges. electric lighting. He had put a direct-acting engine for the electric-light installation on the "Chimborazo" in 1880, and it had been in use ever since. The Author had curtailed his remarks on the subject of the arrangements and circuits of wires on board ship, especially as to the most economical plan of enabling one portion of the ship to be lighted when the other did not require it as at night, and also when the ship was in port; nor had he said anything about the side lights of the ship, or the mast-head lights. Both the ships to which Mr. Hedges had referred had electric-lighting port and starboard lights, and they were very efficient; but there was one drawback, it was always necessary to keep ordinary oil-lamps trimmed ready for use. It was not that the officers expected that the electric-lights would go out; but although the penetration was sufficient with the electric-lights, there was an absence of diffusion, so that, if the least fog came on, the lights, instead of sending their rays seawards, threw a halo in front, red on the port side and green on the starboard side, and that bothered the look-out. The Author had referred to the most economical section of conductor to be used, and stated that he found 1,000 amperes per square inch of section to be the best. That did not seem to agree with practical working, at any rate in the United States; the Edison Company for house to house lighting in New York used a much higher rate. On the new system employed there, on cables carrying 100 or 110 amperes there were 5,000 amperes per square inch, and in the Edison two-wire system 3,400 amperes were used. The reason seemed to be that to get the best economy out of copper cable, it should be worked all day; and in order to compensate for the time when it was not being worked, and for the time when the current passing through was only equal to a few lights, it had to be worked at a rather greater current for a certain period when all the lights were on. If the insulation was good there was no objection to this plan. He was glad the Author suggested the use of foil for safety fuses instead of the unreliable wire. Mr. Hedges had advocated this practice for some time, and he thought that the plan of adopting safety fuses to save the lamps was one which might be followed with advantage. As a rule electrical engineers objected to insert fuses which should protect the lamps; but from a public point of view they were necessary. The Author had mentioned a case where fifty lamps were destroyed by the governor getting out of order. Mr. Hedges had investigated that case, and ascertained that none of the fuses were melted. If they had been put in to save the lamps, there was no reason why the harm done should have been more than the melting of a few of the fuses. Of

Mr. Hedges. course there was the trouble of putting out the lights, but that was better than the large expense entailed. He used an apparatus which inserted a duplicate fuse automatically; the arrangement was designed to put in a second fuse, and so prevent the extinction of the lights, unless a short circuit occurred, when both would be melted. He was not in a position to give any information upon the cost on account of the difficulty of separating the working expenses on board ship.

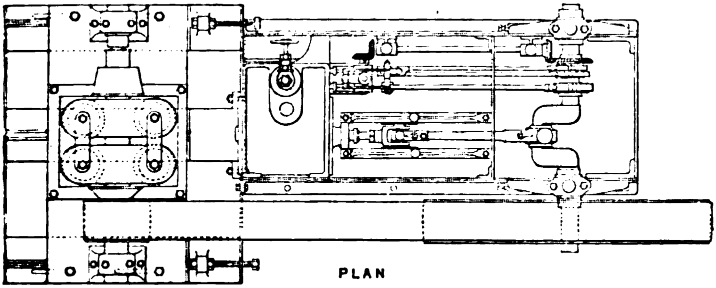
Mr. Paxman. Mr. J. N. PAXMAN said that, although it could not be denied that there were advantages in high-speed engines for certain special purposes, up to the present they had not been able to compete with those of lower speed either in economy or durability. On board ship, where the stoppage of machinery was at times

FIGS. 15 and 16.



SIDE ELEVATION.

Space occupied 12'·4'-0'



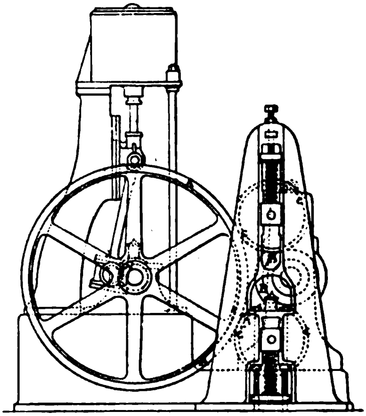
PLAN

COMBINED STEAM-ENGINE AND DYNAMO.

Scale ⅜-inch = 1 foot.

Mr. Paxman. attended with great danger to the vessel, durability and efficiency were of the first importance; repairs also were always more difficult and costly. The sacrifice of space was but small with engines and dynamos combined, as would be seen in Figs. 15 and 16. The firm of Davey, Paxman, and Co. had made several of this type; and an engine, together with the dynamo sufficiently large enough for driving comfortably two hundred lights, would only occupy a space of 12 feet by 4 feet. When it was considered that the machinery was all visible to the attending engineer; also that such engines were easy of access, and could be run for a week if necessary without stopping, these advantages were more than a set-off to the trifling additional space required. It would be noticed that Fig. 17 represented a horizontal engine, mounted upon a wrought-iron box frame forming the foundation, so as to combine lightness and strength. The cylinder was 12 inches in diameter, by 12 inches length of stroke, and the engine ran at one hundred and eighty revolutions per minute. All the parts were balanced. This engine was fitted with Paxman's automatic cut-off gear, and the governors were driven with tooth-gearing, and they would regulate the speed within 2 per cent. with all the load on or off. The dynamo attached to the engine-framing was driven from the fly-wheel with a leather belt 9 inches wide. The dynamo could be readily adjusted to keep the belt tight whilst running. Fig. 17 represented an arrangement proposed for driving a dynamo with com-

FIG. 17.



COMBINED STEAM-ENGINE AND DYNAMO.

Scale [illegible]-inch = 1 foot.

Mr. Paxman. pound friction-roller gear. A was the fly-wheel of a vertical engine; B was the friction-pulley on the dynamo; C C were two friction-wheels lined with stout india-rubber tightly forced on, or vulcanited upon the pulleys. These impinged upon the fly-wheel and dynamo-pulley, one upon the top and the other below. By this means a double grip was obtained, and the liability to slip was lessened by half. By this method, the force exerted upon the armature of the dynamo by these two wheels was nearly opposite, thus relieving it of excessive side-pressure. He desired to come to the rescue of the mechanical governor, which had received very sharp criticism from the Author, and from speakers in the course of the discussion. Two or three leading principles should be taken into account in making a governor, and they were very simple. At the Exhibition held at South Kensington, in 1884, a governor worked practically true, regulating the speed of the engine within 1 or 1½ per cent. In stating that, in low-speed engines, the governors would not run within 5 per cent., and in high-speed engines 25 per cent., he thought the Author must have fallen amongst an indifferent set, for it was not an uncommon thing to have a governor regulating the speed within 2 per cent. He had

TEST of GOVERNORS combined with AUTOMATIC CUT-OFF VALVE for ascertaining SPEED of ENGINE under various PRESSURES of STEAM with and without LOADS, by J. N. PAXMAN.

60-HP. Compound Engine, Cylinders 15 inches and 22½ inches, length of stroke, 24 inches. May 1883.

Test Number.	Steam-Pressure.	Indicated HP. with Load.	Number of Revolutions.	Indicated HP. without Load.	Number of Revolutions.
1	lbs. 45	83·6	102·00	17·18	103·50
2	60	128·0	102·25	18·00	103·75
3	75	137·0	102·25	17·70	103·50
4	90	135·5	102·00	17·20	103·50

20-HP. Double Cylinder, Semi-portable Cylinders, diameter 10½ inches, stroke 14 inches. May 1883.

Test Number.	Steam-Pressure.	Indicated HP. with Load.	Number of Revolutions.	Indicated HP. without Load.	Number of Revolutions.
1	40	32·0	138·00	11·5	140·0
2	50	40·9	138·00	10·0	139·5
3	60	47·7	138·50	10·4	140·0
4	70	66·0	138·75	11·2	140·5

Mr. Paxman. the particulars of some trials in May, 1883, which he thought might be of interest to the members. He had that day received some particulars of a trial of a small single-cylinder engine, where the governor ran within 1½ per cent., all the load being on and then immediately taken off. He had been told that that was sufficiently regular for driving electrical apparatus. In the case of the compound-wound dynamo, he was informed that it did not matter so much about diminishing the speed with a decreasing number of lamps. In making governors, the objects should be to have as little friction as possible, reducing it almost to nothing; and in the second place, there should be no reservoir for steam. He advocated automatic cut-off and governors driven with gear, not with a belt. One of the chief disadvantages in the governor was that the slide-chests were generally rather large, and the throttle-valve at some little distance, so that there was a large reservoir of steam; and if the load was taken off, sufficient power was stored up to drive the engine several revolutions with increased speed. With automatic gear there were only the thoroughfares to fill, and immediately the steam was cut off there was no storage, and no increase of speed. The throttle-valve should be in equilibrium and a good fit, so as to prevent leakage. Again, the governor should be able to control the engine without an excessive movement of the balls. Keeping these objects in view, engines could be well regulated within 2 per cent. In conclusion he would ask if the Author's electrical governor could be made to control the engine within 2 per cent., as certainly was done by the mechanical governor. Like the governor just mentioned, it could not anticipate the reduction of power, and therefore could only modify the speed of the engine after the power was increased or decreased.

Mr. Sellon. Mr. PERCY SELLON remarked that attention had been particularly drawn to the curve of the compound-wound Victoria dynamo (Fig. 1). Mr. Siemens had gone so far as to say that he would reject a dynamo from which such a curve had been obtained; but Mr. Sellon thought such a course would be uncalled for. The objection raised was, that no allowance had been made for fall of potential in the leads on the curve: the curve in question had been taken from a dynamo intended for ship-lighting, where the loss of potential in leads was necessarily small; and if the curve was examined, it would be seen that a drop of 2 volts of potential had been allowed for, representing 4 per cent. of the total electromotive force of the machine, and that, according to his experience, was what actually obtained in ship-lighting. He agreed with

Mr. Siemens that, for ordinary purposes in installations on land, **Mr. Sellon.** a large loss had to be allowed for, in many cases as much as 10 per cent.; and for that reason it was desirable to wind dynamos for the particular circuits on which they were intended to run. It had also been found in practice that a greater drop than would be accounted for by loss of potential in leads was necessary, to allow for the slight rise in the speed of engines as the load on them was lowered. A further point, and one which had been raised by Dr. John Hopkinson, was whether it was practicable to connect compound-wound dynamos in parallel. The general impression, after Dr. Hopkinson's remarks on that point, was, he believed, that it was not advisable to do so in practice, and that shunt machines were preferable for that purpose. It had been found, however, that if a third wire was carried, connecting up the series wires of two or more compound machines at the point where the series wires joined the armatures, so that the whole of the series wires might be considered to be in one parallel, a reversal of polarity of any one machine was, within considerable limits of speed, guarded against, and there was an equal distribution of current among the series coils. Dr. Hopkinson had mentioned that he had found that if one of a number of compound machines connected in parallel showed from any cause a higher electromotive force than the remainder, that particular dynamo would tend to build up current, and so to do the whole external work, to the exclusion of the other machines. Mr. Sellon had found, however, that connecting up machines in the manner stated obviated this difficulty within the limits required in actual working. Attention to such points as these had brought compound-wound machines to the pitch of perfection shown by the graphic curve of the Victoria dynamo; and taking in view the undisputed advantages of compound machines for both ship-lighting and ordinary purposes, it appeared obvious that they would be even more extensively used in the future than they had been up to the present. As representing one of the companies who had perhaps had as great an experience with storage batteries for ship-lighting as any, he might say that they had used them largely for manufacturing processes and internal lighting, and some had been in continuous operation longer than a year without material deterioration. For many purposes secondary batteries would be most useful in ship-lighting; for instance, the same dynamo which internally lighted the vessel might charge the accumulators, which would supply power ready to hand for motive power or propelling a steam-launch or torpedo-boat, and so save the time lost in getting up steam.

Mr. Sellon. He believed a demand for secondary batteries would create a supply of so satisfactory a nature as to ensure their very general adoption on board ship for motive-power purposes; but he was unable to give any information with regard to the increased cost of lighting occasioned by the employment of secondary batteries.

Mr. Oughterson. Mr. G. B. OUGHTERSON said that the Author had stated, in reference to direct-driving dynamos: "Besides these objections, direct-driving of the dynamo-armature from the crank-shaft of a fast-speed engine is very popular, and such engines cannot be relied on at speeds of over six hundred revolutions per minute for any lengthened period." A Table issued by Messrs. Sautter, Lemonnier and Co., at the Vienna Exhibition in 1883, contained instances of two hundred and seventy-six applications of Brotherhood's direct-driving engines to dynamos, two hundred and thirty-six of which were driven at speeds over that given in the Paper as a maximum, and out of the two hundred and thirty-six there were one hundred and six working at sixteen hundred revolutions a minute. Amongst the applications made for electric lighting of steamships, there were a great number of direct-driving engines attaining speeds much above six hundred revolutions. In the case of the "Himalaya," the engines ran at six hundred and fifty revolutions. The electric lighting engines at the Royal Laboratory at Woolwich, driving sixteen-light Brush dynamos, and indicating 20 HP., ran at eight hundred and fifty revolutions. He might also mention the case of two 6-inch engines, working with 70 lbs. steam-pressure, and each driving a sixteen-light Brush dynamo at eight hundred and fifty revolutions per minute, that had been running for eighteen months consecutively, on an average eleven hours a day, without needing any repairs. With reference to governors, the Author had laid down the law that no mechanical governor would "keep the engine within 5 per cent. of its normal speed, with a load varying 90 per cent., and a boiler-pressure varying 10 lbs. per square inch." In some experiments that he had made with a Brotherhood direct-driving engine, the engine had to run, to give out its maximum power, with a steam-pressure of 40 lbs. It was started with that pressure at the boiler, and the governor was set for a speed of six hundred revolutions per minute. The pressure was allowed to rise in the boiler from 40 lbs. to 75 lbs., without any increase in the speed of the engine. The arc light was suddenly extinguished, and the rise of speed at the instant of extinction was only twenty revolutions above the normal, and then the speed settled to the normal in two seconds. That showed that a mechanical governor could at any rate do what the Author had said it could not accomplish. He should like to say a few words about the flexible coupling and might mention that Brotherhood's patent flexible coupling, had been put up exactly twelve months ago, to drive the line-shafting at the works of Messrs. Simpson and Co., and the leather had been withdrawn for exhibition at this meeting. It had been running regularly at a speed of eighty revolutions, carrying 40 HP., and it had made in all about fifteen million revolutions. During this time it had driven twenty-three lathes, three planing-machines, a circular saw, and some woodworking machinery. The leather would be found on inspection to have stood the immense strain remarkably well. He had had considerable experience with this system of coupling, and he thought that for ship-lighting some coupling of that nature ought always to be interposed between the engine and the dynamo, so as to relieve the bearings should irregular wear take place. **Mr. Oughterson.**

Mr. Mordey. Mr. W. M. Mordey observed that the sensitiveness of the Author's electric governor must depend largely upon the ease with which the currents could be generated in the revolving copper disk. The resistance of copper varied considerably with temperature. The rise in the resistance of pure copper was 0·388 per cent. per degree Centigrade, so that as the temperature increased from the action of the Foucault- or eddy-currents generated, as well as by the ordinary changes of temperature, the resistance would rise considerably. As at a given speed and in a given field the currents would be inversely as the resistance, it followed that a rise of 10° Centigrade would mean a fall in the eddy-currents of about 4 per cent.; and a rise of 25° Centigrade, which was not too great a rise to imagine as taking place, partly from the action of the current in the disk, and partly from ordinary causes, would mean a loss of sensitiveness in the governor of about 10 per cent. He wished to ask the Author whether it had been necessary to use any sort of temperature correction on account of that supposed fault, or whether the fault existed? A good deal had been said about the question of low-speed dynamos on board ship. The Author had stated that, in order to get a dynamo to run at a low speed suitable for direct driving for ship work, it must necessarily be largely increased in weight and bulk. Although it might be necessary sometimes to increase the size of the dynamo, in order to get work from it at a low speed, he did not think that in all dynamos that was the case. He was well acquainted with some dynamos—and he believed it was the case with all good dynamos—in which the speed could be reduced considerably without any appreciable increase either

Mr. Mordey. in size or weight. He was acquainted with one dynamo, of a pretty well-known type, supplied to run at a reduction of 25 per cent. on the very moderate normal speed and to do full work, without any appreciable increase in size or weight, and without any other loss, or without any circumstance that would tend to render low-speed driving in such a case objectionable.

The Author had referred to the important point of the insulation of the conductors of dynamos, but he had said nothing about another point of equal importance, though often overlooked, viz., the insulation between the iron frame of the machine and the earth, or the metal of the ship, as the case might be. In the original regulations for the prevention of fire-risks issued by the Committee of the Society of Telegraph Engineers, the recommendation appeared that the insulation-resistance between the conductors of the dynamo and the metal frame of the machine should be as high as possible (that, of course, was well known); and a precaution was also mentioned, that the insulation between the iron frame of the machine and the earth should be attended to. In the later issues of the regulations he believed that precaution had been omitted, he did not know why. It appeared to him to be a mistake. The insulation-resistance between the conductor of the dynamo and its frame must necessarily be rather low when the machine got hot, for the simple reason that the resistance of dielectrics followed an exactly opposite law to that of metals, becoming much lower as the temperature rose. In all dynamos there was more or less heating when the machine had been working a considerable time, therefore the insulation-resistance between the conductor and the frame must fall. There were other circumstances also which tended to reduce that insulation-resistance, such as the expansion of the conductors, and perhaps the fact that filings or metallic dust from the brushes might lodge. If the insulation-resistance between the conductor of the dynamo and the frame were attended to, and also insulation between the frame and the earth, there would be an additional link in the chain of insulation, the breaking of which would be more difficult than when the machine was put on an iron base, and no precaution was taken to prevent earth contact. That was particularly necessary in the single-wire system, and less necessary, but still very necessary in the double-wire system. Of course there might be one contact between the conductor of the machine and the iron, and it would do no harm if the leads on the circuit were insulated; but if the frame was insulated from earth, a single fault, even if it was a "dead earth" on the external circuit, in addition to the dynamo

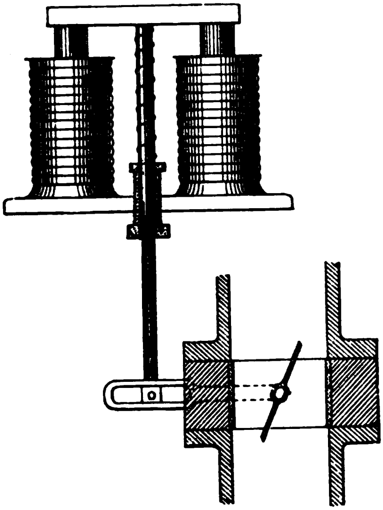
Mr. Mordey.

fault, would do no harm, although very undesirable. It was less difficult to insulate the leads in the external circuit well than it was in the dynamo, because space was not so valuable, and the thickness of the dielectics might be much greater. Therefore he thought that the insulation-resistance of the frame and of the machine should receive as much attention as any other part of the system. Mr. Sellon had spoken of the working of compound dynamo machines in parallel circuit with reference to some observations by Dr. Hopkinson. Of course anything stated by Dr. Hopkinson on the subject of dynamo machines must be received with a great deal of respect; but he agreed with Mr. Sellon as to the practicability and ease of working compound dynamo machines in parallel circuit. In fact, he believed that he had been the first to use, and, as far as he knew, had originated the method sketched by Mr. Sellon. The rationale of the process was simple. If not only the shunt-circuits of the machines were parallel, but also the series-circuits, it followed in the case of two exactly similar machines that—the loads being always alike when speeds were alike—if the machines were being driven by belts which were not of the same character, or if the pulleys differed a little in size, any tendency of the one to lag would throw more work on the other, slightly pulling it up, and allowing the lagging machine to "race." In that way they exercised a mutually adjusting " power," and would work with the greatest ease, even if considerable liberties were taken with regard to the position of the brushes. And not only would two similar compound dynamos work in parallel circuit; but any number of compound dynamo machines of varying size, power, or speed, would work well in parallel circuit; and each machine would take exactly the proportion of power that it ought to take, and would do exactly the amount of work that should fall to its share. There was only one precaution to be observed in such a case, in addition to that of joining up the machine, so that not only were the brushes parallel, but also the terminals, namely, the resistance of the series-circuits of the various dynamos must be inversely proportional to the currents they supplied. In that case, as the fall of potential through the series-circuits would always be alike in all the machines, whatever the currents, and whatever size they were, and the current in each individual field magnet being exactly right, they would work in a perfectly satisfactory way. But that did not cover the whole subject. Further examination would show that the characteristic curves of such dissimilar dynamos ought to have similar formations to exercise that mutual adjust-

Mr. Mordey. ing power with the greatest effect. Still for practical purposes those two precautions were amply sufficient to enable compound dynamo machines to work in parallel circuit. Another observation made by Dr. Hopkinson related to the amount of correction in compound machines. He could not agree that the smallness of the correction played so important a part as had been imagined. If smallness of correction were necessary for good compounding, it would be impossible to use compound dynamo machines in places where it was necessary to have the machine a considerable distance away from its work, and it would not be possible satisfactorily to compound a dynamo machine, so that it would maintain a constant potential at a distant point of the circuit with a varying load. He might be permitted to state a case, perhaps an exaggerated one, to illustrate his meaning. Let it be imagined, that at some large house or hotel there was a group of lamps—the lamps in the house might in such a case be considered as one group, being within a short distance of one another—and that on account perhaps of the cheapness of power at some distant place it would be economical to work a dynamo, the loss in the leads might be very considerable, and yet there would be no want of economy. A dynamo might be so distant—not in miles or in yards necessarily, but in ohms—that a loss in the leads between the dynamo and its work of 50 per cent. might be permissible. For such a case it would be quite easy to construct a machine so that, with this loss of 50 per cent. in the leads, and varying between the full load and no load, it would maintain a practically constant potential at the terminals of the lamps. Of course such a case would mean that if the lamps required 100 volts the potential would fall from 200 to 100 at the dynamo terminals as the work fell from the full load to nothing. He could find no fault with the curve of the compound-wound Victoria dynamo. He agreed with what Mr. Sellon had stated, that in many large houses and ships, where all the work was near the dynamo, and where the distribution of the lamps was not from a distant part of the circuit, but began almost immediately after the leads left the dynamo, it was unnecessary to have a great fall in the electromotive force. In fact, with such a fall, and only a few lamps lighted, at whatever part of the circuit they might be, those few lamps would be very dull; and it would be necessary to increase the speed of the machine in order to bring the light up to the normal power. He might be permitted to say another word with regard to the curve in question. Although the Brush Electric Light Company had for several years manufactured dynamo machines for maintaining a constant potential at the terminals in electro-plating Mr Mordey. operations, where a change in the number of articles in the vat was constantly going on, and where, on account of the necessity of obtaining an even deposit on all the articles in the vat, it was necessary to maintain almost a constant potential, yet the making of compound machines was undertaken in the first place on the machine from which that curve was taken. The winding of the machine was calculated by Mr. Watson, who originated the very excellent method of compounding that was used; it was calculated from experiments and put on to the new machine. The machine was run, and at the anticipated speed, without the slightest modification or alteration, it gave the very satisfactory results shown by the curve. That spoke, he thought, very highly for the method. It would be interesting to know what the first curve of the first compound-wound Siemens dynamo was like.

Mr. Cooper. Mr. CHARLES FRIEND COOPER said that the details given by Mr. Paxman, with regard to mechanical governors, might almost make

FIG. 18.



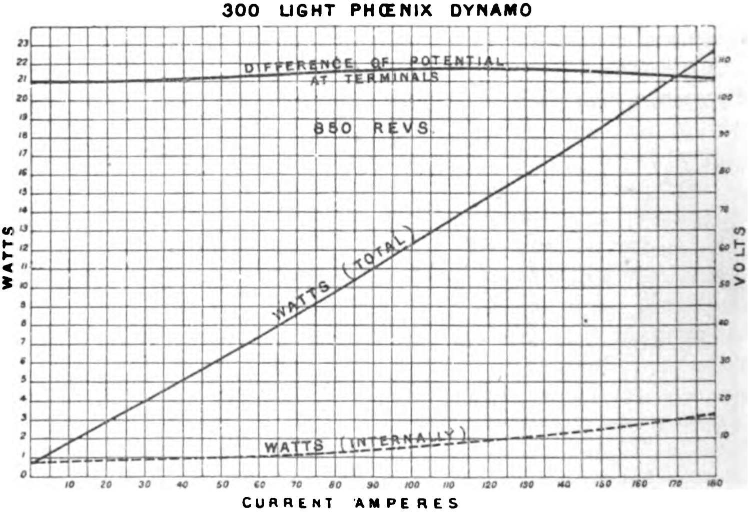
ELECTRIC GOVERNOR.

In compound machines for constant potential coil in the circuit.
For constant current coil in a shunt to terminals.

engineers regret that they had anything to do with electrical governors. Nevertheless all the mechanical governors with which he was acquainted were actuated by a difference of that which it was desired to keep constant, namely the speed. In other words

Mr. Cooper. the speed of the engine must alter before the throttle-valve (or link of expansion-valve) could act. The speed must alter before the governor could act to regulate that speed. He understood that the Author in his electric governor revolved the copper-disk in the field of an electro-magnet, wound as a shunt to the main circuit. This appeared to him liable to the same objection as the mechanical governor, because the electromotive force was dependent upon the speed, and therefore the speed must alter before the electromotive force could alter. He would ask if it was not possible to make a modification of the governor in which the electro-magnet should be wound in main-circuit, in which case the strength of field would vary with the current and not with the electromotive force? Now, in a self-regulating dynamo the current was the variable factor, the object of such a machine being to keep the potential constant for all currents, and therefore the most direct governing would be by that variable. In a governor suggested to him by Mr. Esson, Fig. 18, consisting of a plain double solenoid wound in main-circuit, the pull on the cores due to the current was opposed by a spiral spring, and the cores were connected to a lever attached to the throttle-valve by means of a rod, which might equally well be attached to the link of an expansion-valve. The action of this hardly required explanation.

Fig. 19.

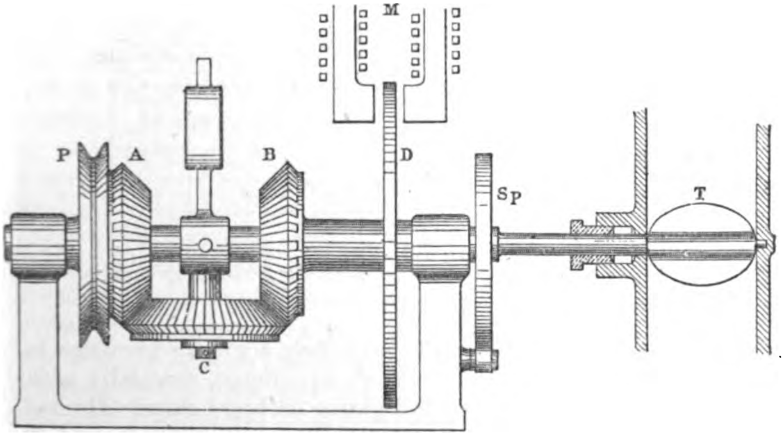


The figures to the left represent thousands of watts.

When extra lamps were turned on, or more current flowed, the cores of the solenoids were pulled down against the spring and the throttle-valve was opened; if the current was reduced the spring predominated and the valve was closed. He here directed attention to a diagram (Fig. 19) of the characteristics of a three-hundred-light self-regulating "Phœnix" dynamo, showing that the current was almost proportional to the watts produced. Fig. 20 showed a modification of the Author's governor, which was actuated by variations of the current. The copper-disk D revolved in a field M produced by the main current, and was secured to the boss of one of the three bevel-wheels B which was loose on the spindle. The spring Sp acted in opposition to the turning of the spindle one way, and the wheel itself geared into the centre wheel C whose axis was keyed to that spindle. The disk was driven through the centre wheel from the third wheel A and pulley P, which was loose on the shaft. Now when the resistance to the revolution of the disk D was increased or diminished (due to more or less current flowing in main current) this centre wheel C either rode up or down, and its axis being fastened to the spindle turned it, and thus opened or closed the throttle-valve T; that was, it regulated the opening of the valve without reference to the electromotive force or speed. He was familiar with this arrangement as applied to a transmission dyna-

Mr. Cooper.

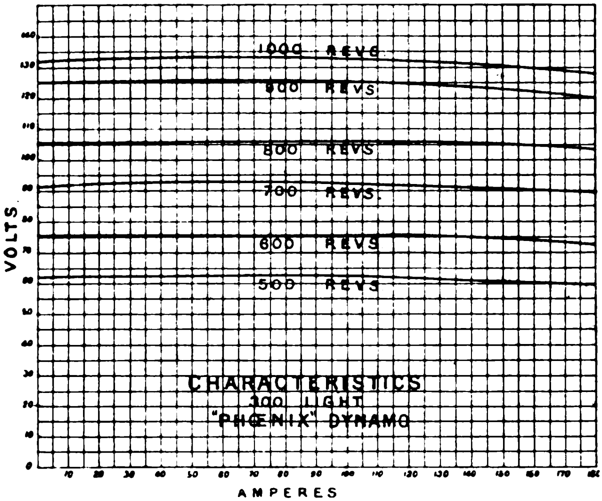
Fig. 20.



Modification of Jamieson's Electric Governor. 1884.

Mr. Cooper. mometer. Referring to Fig. 21, it would be seen that the characteristics of this machine were practically the same at one thousand revolutions and at five hundred revolutions, as well as at intermediate speeds—the difference of potential being not more than 4 volts out in any case.

Fig. 21.



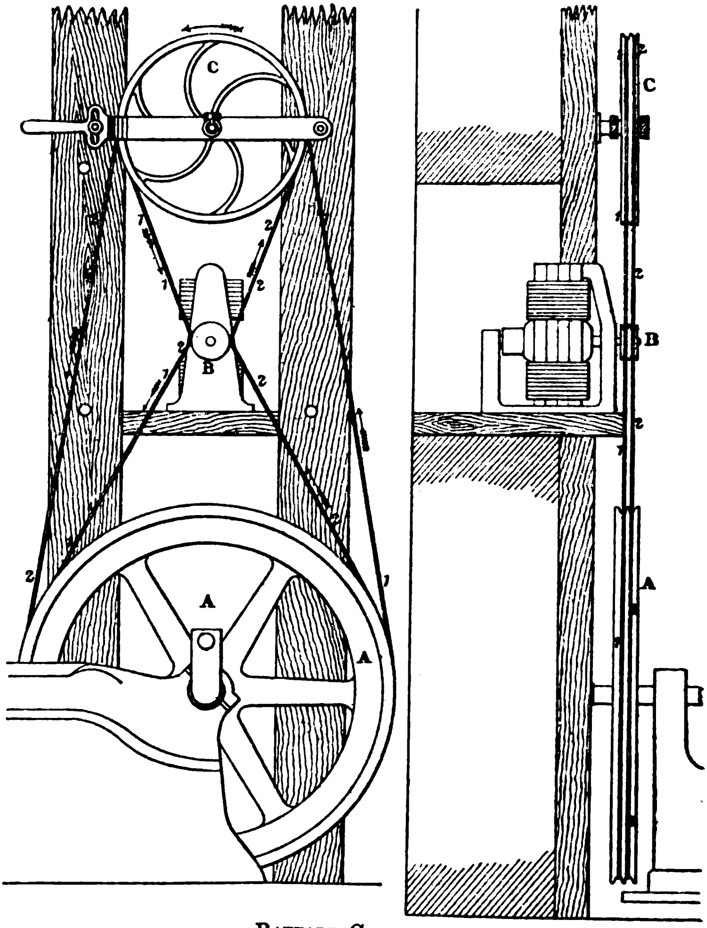
Mr. Joel. Mr. H. F. Joel said it would have been a great advantage to have had the benefit of the Author's experience, especially with regard to the failures of electric lighting on board ships. He had known a failure in an installation, where the dynamo was spoiled by the bursting of a steam-pipe close by. The steam saturated the insulation of the dynamo, and the dynamo was started again, and broke down. He had known other cases where the two small wires connecting the lamps had been placed close together, and fixed to the ship's sides under one staple, short-circuiting being the result. As to the question of the double- or the single-wire system, the former was the only safe system to use; it was easily fitted, but not the latter. Only one reason could be adduced in favour of the single-wire system, namely, the keeping down of the estimate. Mr. Siemens had stated that he had often to go 2 or 3 feet from a single wire through the woodwork to get to the ship's side. But the difficulty did not end here. There was the making of the joints between the insulated wire and the ship's side, and those joints, which were always hidden, were the great drawback.

In the double-wire system the joints were exposed and they could be so well made as not to fail. If the dynamo broke down, if there was a leak in the insulation, the single-wire system offered every facility for complete failure, and great difficulty in localization of the faults. Mr. Farquharson had pointed out that the two wires being fixed together might be a disadvantage; but by putting them 18 inches apart, or even 10 feet apart, they afforded a perfect system. In the Board of Trade Regulations there was a special clause against the use of earth: "No conductor shall be connected with earth." In the Fire Insurance Regulations also no ground-circuit was allowed. The danger of the ground-circuit increased ten-fold on board ship, owing to the difficulty of preserving the insulation, and on that account it should not be permitted. Alternating-current machines, in which the currents were much varied in intensity through the alternating action, tried the insulation more than the continuous-current system, and on that account they should not be allowed under any circumstances. As the result of considerable experience, he found that accumulators were still very unsatisfactory. With a man to superintend who thoroughly knew how to clean them, they might be used successfully on board ship, because they could be run direct from the main engine. They acted as a governor to keep the lights steady, and in case of a breakdown of the machines, the accumulator would give sufficient power to keep the lights in action; for those reasons they might be useful. The magnetic action of the dynamo machines, and also the action of the electrical currents in the wires on the ship's magnetic compasses, had not yet been referred to. A serious error might possibly arise from either or both of these causes. The influence of the electrical-currents in the wires, if they passed within, say, 10 feet of the compasses, would be appreciable, especially when the current was started or stopped, and he would direct the attention of naval officers and engineers to that point. Precautions could easily be taken to prevent any error on this account; first, by maintaining the electric light in full action whilst the ship's compasses were being adjusted, stopping and starting repeatedly during the time, and noting the errors, if any; secondly, by running the double-wire system with the two wires nearly together, say 3 inches apart only, so that the currents going and returning would neutralize the action of each other. Mr. Joel.

Mr. A. Reckenzaun wished to bring before the members an ingenious method of driving dynamo-machines of small power invented by Mr. Raffard, of Paris. The chief advantage of that Mr. Reckenzaun.

Mr. Reckenzaun. kind of gearing was its silence; and secondly, it occupied only a small amount of space. The distance between the centres could be very small. With a 4-feet flywheel, a 2-feet stretching-wheel, and a 6-inch pulley, the whole distance from the top to the bottom was only 8 feet 6 inches. Then there was a uniformity of motion,

Fig. 22.



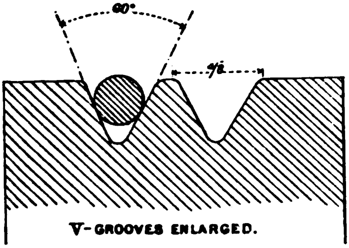
Raffard Gearing.

A, Fly-wheel of engine, 48 inches in diameter, 170 revolutions. B, Pulley on dynamo, 5 inches in diameter, 1,632 revolutions. C, Stretching pulley, 24 inches in diameter, 340 revolutions. 1, 2, Catgut band, ¼ inch in diameter. I. HP. = 2. Start at 1 nearest B, follow arrows, Nos. 1 corresponding to grooves nearest the dynamo, and Nos. 2 furthest from it.

Mr. Reckenzaun.

and, above all, equilibrium upon the driving-pulley of the dynamo, so that the stretch upwards was as great as the stretch downwards, and the dynamo could be easily lubricated. The inventor had told him that if the whole arrangement was made theoretically correct, the bush could be taken out of its bracket and worked in air; but of course that was an exaggeration. The gearing was represented in Figs. 22 and 23. It would be seen that one long piece of catgut band was placed upon the pulleys to produce the desired effect. The distance between the centres A and C could be materially reduced without detriment. The dynamo-pulley was almost completely encircled by the band, and slip was avoided, even when the band was slack. With small dynamo machines, running at a speed of from fifteen hundred to two thousand revolutions per minute, lubrication was rather difficult; but in the case he had described lubrication was easy. Another advantage in the bearing was that the armature could be fitted closer to the poles of the field magnets.

FIG. 23.



With reference to accumulators, they had been in the market for three years, and a good deal had been said for and against them. During the first few weeks much was said in their favour, but it had since been found, that very little could be done by them. They had, however, been improved considerably within the last few months; but he was aware of only one instance in which accumulators had been introduced on board ship; that was in the case of the "Chimborazo," where a small installation was fitted with twenty-five 1-HP. accumulators of the Faure, Sellon and Volkmar type. From the report of the engineers, it appeared that they had given every satisfaction during their voyage to Australia and back, but half-way on the voyage the dynamo machine got injured, and the whole had to be given up. That, therefore, was not a proper test as to how long accumulators would last. He believed

Mr. Reckenzaun. the time would come when accumulators would be used as regulators on board ship.

Mr. Albright. Mr. J. F. ALBRIGHT said he had gained experience in the lighting of between thirty and forty vessels. The Paper marked a time when electric lighting for ships was beginning to be dealt with in a thorough and scientific manner. Mention had been made of several essential points to be considered in selecting the dynamo to be employed; but there was one point that he regarded as all-important, to which no allusion had been made. How was the machine to be protected from oil, water, and dirt? He had found that the action of these three things, combined in many places with high temperatures, broke down the insulation more quickly and certainly than any other cause. Recently the machines of two well-known makers had to be removed, after a few months, solely on this account. A good deal had been said about various engines and various methods of using them; but he thought that perfection in dynamo-driving on board ship was still a long way off. Take the Westinghouse engine, for instance. He could not say that those he had had to do with were thoroughly satisfactory, and he believed that even in the "Arawa," which had been alluded to in the Paper, matters had not gone smoothly in the engine-room. He would rank Brotherhood's improved engine, or Willans compound engine, far before it; nevertheless, he considered all those high-speed engines, so far as they were known, eminently suited to run in the shops where they were made, and fairly reliable in careful hands on shore, but pitfalls for the unwary when placed in cramped, dirty holes, generally cut out of the coal-bunker on board ship. There were special circumstances under which only those engines could be used; but as a rule he held that the average marine engineer, whose time was well filled up, should have, to start with, an engine of which he could see the working parts, of the same type as the donkey-engine, and pumps, inasmuch as he understood their management; and if the rest of the plant was well-found and placed, everything would be successful. As to gearing, belt-driving had not found much favour, but endless rope-gear, with one guide-pulley, proved satisfactory. It had nearly all the advantages of that alluded to by Mr. Reckenzaun. It was easily renewable, it worked with a very short distance between centres, well within the range of the 8 feet referred to, and would be sufficient for two-hundred-light plant. The strain throughout was even, and not excessive, and in case of any unforeseen accident, ropes could always be found on shipboard, which would enable the lamps to be lighted. Mr. Mordey

Mr. Albright.

had stated that the frame of the machine should be insulated from the ship; but how could that be done, except with a rope or belt-driving? With any form of direct-driving or friction-driving, how was it possible to insulate the machine from the engine, and the engine from the steam-pipe? He had also known multiple rope-gear work extremely well. Friction-gear, as at present arranged by Messrs. Siemens Bros., had no doubt done good service, and permitted of the transmission of the full power without serious slipping. It was, however, absolutely necessary to keep the pulley entirely free from oil, wet, or dirt—no easy matter on shipboard. He was also of opinion that in this arrangement there was a want of stability in the machine, which involved considerably increased wear and tear. Generally he thought that placing the machines in some dark, inaccessible, corner was courting neglect and failure, and that the electrical engineer should insist on proper and sufficient space being provided. Referring again to the dynamo, he always found that in spite of every precaution the factor of safety for marine work must be higher than for land work; in other words, a machine whose normal output was, say, two hundred lights for land work, should be only expected to suffice for about one hundred and fifty on shipboard. In this respect he went further even than Mr. Siemens. The Author had given some interesting figures in regard to the effects of gyration, but looked at carefully they appeared to him to prove that the effects often ascribed to gyration must be traced to some other source. He had known dynamos of the large-disk type run well athwartship, while dynamos of the drum-armature type became heated. He thought the time when trouble was to be looked for was when a ship had a constant list for several days, and that the heating then occurred owing to the end pressure on the collar, and also partly to the fact that the oil did not run freely up the inclined shaft and bearing. Whatever the cause, the result was the same. As a general rule athwartship dynamos were a mistake. He thought the Author placed the single-wire system in a too favourable light, but this was perhaps due to his renunciation of it having been recent, as only this time last year he considered it theoretically correct and permissible with due precautions. As a matter of fact the single-wire system necessitated the branches in most cases being double, and thus the saving in money was chiefly in the mains, and would not be more than about 2 per cent. of the whole cost. It also appeared certain that even where copper washers were used at the joints with the ship's skin, the two metals would corrode, Mr. Albright. and ultimately introduce resistance, and he believed that at a period when the single system wanted re-wiring, the double system would still be intact. Dr. Hopkinson had already explained the difficulty of testing any single-wire system, and Mr. Albright agreed that it was a very important point. An advanced advocate of single-wiring once said to him that all the double-wire work was generally more or less earthed in a fortnight, to which he naturally replied, "Then all your single-wire work must be generally more or less short-circuited in a week;" but no advocate of the single-wire system would ever allow that. He did not approve of electrical specifications, as, with some exceptions, they were so often only a nuisance, and did not after all ensure good work. Then again, the inspector who had to examine the work paid a few casual visits to the ship, and wound up by making an insulation-test, having probably never wired a ship in his life. He had known of instances in which full tests were arranged for and made at the close of the work by an inspector. High results were obtained, and every one was satisfied, nobody at the time being aware that the turning off or on of a single switch rendered the test valueless. He should like to know from the Author at what stage of the work he considered 10,000 ohms per volt were obtainable; his own experience was that it was only before the cuts-out, fixtures, and switches were in place, and he doubted if any tests made after these were up were ever influenced by want of insulation in the wires, unless some gross defects existed, such as a short circuit or dead earth. When the fixtures were up, the surface leakage at the various points was so great with the damp atmosphere on shipboard, that tests designed to detect imperfect insulation became almost impossible. He thought that an insulation-test made when the dynamo was at work and the ship lighted, giving 200 ohms per volt, might in all ordinary cases be considered satisfactory. It would be interesting to know what the Author considered good arrangements for masthead and signal lights, which had to be impervious to wind and weather, and yet removable at a moment's notice; and also how he would specify that the wires fitted in the stoke-hole should be protected from the heat, which destroyed all ordinary insulation. In conclusion, he would say that it was only by carefully considering these various points, by arranging the fittings so that they were almost proof against dirt and water, and designing all things in the most simple manner, while at the same time making them exceedingly strong, that an electric installation on board ship could be expected to keep in order any fair length of time. But while considering all these questions carefully, and seeing that the specification, if there was one, was sound, he would say to the intending purchaser, "Above all things put your work into good hands." Mr. Albright.

Mr. E. A. Cowper said that he had seen the gearing illustrated by Fig. 22, for driving a lathe, thirty-five years ago, as designed by Mr. Lane, then a draughtsman at the London Works, Birmingham, and he believed it had appeared in the "Mechanics' Magazine." Mr. Cowper.

Mr. Alfred R. Sennett said the difficulty suggested by Mr. Mordey, with reference to the Foucault currents in Mr. Jamieson's Electric Governor, could be overcome by the employment of a brake in conjunction with the wheel, which might then be of any material, not necessarily a conductor of electricity. But he thought it was a mistake in such governors to require electricity to do the work of governing. In such devices it was preferable to employ electrical energy merely as a governing agent, which would cause the energy of the motor itself to be utilized in performing the mechanical operations necessary for varying the expansion, actuating the throttle valve, or whatever was thought advisable. The governing device, in which one of the wheels moved bodily round the shaft, was a modification of the chronometric governor of the late Sir William Siemens, in which use was made of an encyclic train. Mr. Sennett then explained the governor of Sir William Siemens which had been successfully employed in regulating steam-engines, and he pointed out how a light disk, provided with an electric brake, so as to convert it into an electrical governor, might be substituted for the conical pendulum; in which case the electricity would only be required to actuate a light and delicate brake, the work itself being performed by the motor. Sir William Siemens employed the energy stored up in a heavy revolving ball; but Mr. Sennett did not think it was correct to endeavour to govern the action of an electrical circuit by the speed of the engine. He considered it preferable to render the speed of the motor as uniform as possible; but to control the electrical energy either at the dynamo, or by providing means for absorbing any abnormal amount of electrical energy. The Author had stated as a requirement of the dynamo, that it should give a constant electromotive force at a constant speed. He could not agree with him in this respect. A more valuable electrical generator would be one in which a reasonable fluctuation in the speed might take place without producing any difference in the electromotive force, and he thought that this would not be a problem very diffi- Mr. Sennett.

Mr. Sennett. cult of solution. Suitable means, for instance, might be provided, so that the strength of the magnetic field might be diminished as the speed of the generator increased, and the electromotive force be thereby rendered constant. The breakage of lamps upon the passing of an abnormal amount of current was probably due more to a sudden molecular shock experienced by the filaments than to the increased temperature, which lasted only for a short space of time; and this he considered was to some extent borne out by the fact, that the life of lamps was increased by adopting the precaution of heating them up gently upon lighting, and diminishing the temperature gradually upon extinguishing them. The question in his mind was whether damage to incandescent lamps did not occur in a space of time so short that the effect was imperceptible to the eye; and he thought that advantage would accrue from the use of a battery of accumulators placed in multiple with the lamps in the branch nearest the dynamo, as this to a great extent would take up any increase of electrical energy due to a sudden rise in the electromotive force. The Author had given only a brief review of the advantages which must accrue from the employment of the electric light on ship-board; he should like to know if the premium of insurance of ships was reduced on its adoption. The Author had mentioned the danger arising from the storage of inflammable oils, paraffin, &c. The risk, however, was not so much dependent upon the actual storage, but rather in taking the inflammable materials from store, and in their subsequent use. The safety of ships from fire would be greatly increased by the employment of accumulator hand-lamps; which were self-contained combinations of an electrical accumulator with a 5- or 10-candle power lamp, the weight of which with a sufficient storage capacity for a reasonable length of time need not exceed from 4 to 7 lbs. A number of these, each provided with a switch, so that they might be lighted and extinguished at will, might be hung in various parts of the ship, and employed in such operations as examining the propeller shaft, the cargo, the coal bunkers, &c., and the use of matches be prohibited. He was pleased to hear the arguments by some of the speakers against the employment of the single-wire system; he should like to ask the Author what was the money balance in favour of this system, after deductions had been made for the expense of fitting it up, with the extra care and precautions necessary. As the lamps must of necessity be pretty close together, and not far distant from the generator, he considered that the extra resistance due to the double lead was not a point of much moment. It was clear from the remarks of several of the speakers

Mr. Sennett.

that electrical accumulators were not regarded with much confidence at present. Mr. Sellon had mentioned accumulators, which had been in constant use for more than a year with satisfactory results. He might state that Dr. Frankland had had a battery of his accumulators at work performing general domestic electric lighting for about two years. With reference to the relative cost, he should like to know if the Author's comparison was based upon the number of lamps employed, or upon the relative intensities of illumination? He should have thought that in all cases where the number of lights was equivalent to, or in excess of, the number stated by the Author, in one case two hundred, the cost would have been considerably below that of oil or candles. He doubted whether any valid objection could be raised to the employment of anti-friction rollers in conjunction with shafts running at high velocities. It appeared to him that, as in the case of dynamo-electric machines, the pressure on the bearings was so very uniform, more especially in gearing, such as Mr. Reckenzaun had explained, good effects would result from running the shaft in oil on anti-friction wheels, say 1 foot to 2 feet in diameter; this arrangement would offer great facilities for the dissipation of any heat that might be generated. The Author mentioned that a reducing valve was employed with advantage when working off the main boilers, thus wire-drawing the steam. This seemed to him an unscientific method; why not vary the degree of expansion in the engine? Mr. Hedges had stated that a difficulty had been experienced in employing electric light in the port and starboard lights on misty nights, on account of its producing such an illumination of the mist, as to be prejudicial to the look-out. He took it that incandescent lamps were employed; and assuming the optical apparatus to be the same for the electric as for the oil-light, and the space occupied by the filament and the flame of the oil lamp to be about the same, a similar effect should be produced. He, therefore, thought the difficulty was due merely to the difference in the illuminating power. The arc light, since it was rich in the more refrangible rays, was particularly suited for the starboard light; while the incandescent light, having a preponderance of the less refrangible rays, was more suited for the port light; and if incandescent lights were employed, the temperature of the filament of the starboard light should be as high as possible, whilst a larger mass of filament at a lower temperature would be preferable in the port light. He had had some experience with electric light in submarine operations, and the following suggestions might be of value:—When the lamp was slung from the surface, Mr. Sennett. the diver could not readily get the position and height of the lamp adjusted to suit the requirements of his operations, and it was necessary for him to communicate with the surface each time he wished to alter the position of the lamp; he therefore suggested that the lamp should be suspended from a mass of cork, or any convenient means of rendering it buoyant, and it should be prevented from rising to the surface by a line run through a block attached to a mass of iron or stone lying at the bottom. The diver could then alter the position of the lamp by carrying the iron with the block attached to it from place to place, and could adjust the height of the lamp to a nicety by taking in or letting out more or less of the line.

Mr. Hammond. Mr. JAMES HAMMOND wished to refer to the pressure of a shaft on its bearing as applied to any marine engine. If the shaft was rotating in the bearing, the pressure at the bottom would be greater than the pressure at the top, and consequently the friction at the bottom would be greater than the friction at the top; this would cause the pressure on the one side to be greater than the pressure on the other. Consequently, instead of having the maximum pressure actually at the lowest point, it would fall somewhere near the lowest point of the bearing. Of course if the shaft were actually at rest there would be no pressure at all on the upper half, and every portion of the lower half would sustain pressure. When the shaft was placed fore and aft, the roll of the vessel simply shifted the point of maximum pressure more to one side or the other; but if it was placed athwartships the rolling of the vessel tended to elevate one end of the shaft and depress the other, and so throw the pressure of the shaft against the top bearing and against the bottom alternately. In a machine where steadiness was everything, the proper position would certainly be fore and aft, and not athwartships.

Mr. Beaumont. Mr. W. WORBY BEAUMONT suggested that electricians who had shown ingenuity in inventing new terms should invent another to express the name of what had been called a curve. Though not confusing to those accustomed to characteristic "curves," it might be to those who approached the subject for the first time. With respect to the pressure on the bearings of a dynamo machine, whether placed fore and aft or athwartships, it appeared to him to be a question not as to how much it was when the dynamo was placed with the spindle athwartships, but as to the difference between that and what it was when placed fore and aft; after all, the extra pressure brought to bear was, from a mechanical engineer's point of view, really a very small thing, and would not have

Mr. Beaumont. any effect upon a machine designed by an engineer accustomed to plan machines that should run for any length of time without giving trouble with the bearings. How small that additional pressure was might be gathered from one circumstance. It was shown by the formulas due to Sir W. Thomson that the pressure was proportional to the distance between the two bearings. As an extreme case, to show the application of Sir William Thomson's formulas, the Author had taken a machine in which the armature weighed 500 lbs., the radius of gyration was 1 foot 3 inches, and the distance between the bearings only 18 inches. He thought it would be admitted that there were hardly any, if any, machines made with an armature of that weight with the bearings so small a distance apart. In most machines they would be more nearly double that distance, and, as the pressure upon the bearings was proportional to the distance, instead of having an extra 930 lbs., which after all was not much, they would only have about 465 lbs., and there was no machine made that would be affected by that as an additional pressure. The Author had touched first upon the selection of engines and fittings, and next upon the method of driving. It seemed rather difficult to separate the two, but if they were separated he thought the method of driving should be first considered, inasmuch as it determined what the character of the engine should be. A good deal of difference of opinion had been expressed as to the relative merits of direct-driving engines and of low-speed engines, and in the Paper one or two statements had been made as to the governing of the engines. The Author had stated, with reference to one of the high-speed engines, that in spite of having tried all the best governors, the speed varied 25 per cent. But, as Mr. Paxman had observed, governing was not altogether a question of the governor, but a question of the whole engine. It would be useless, for example, to have the best governor that could be found for some of the donkey-engines that might always be heard grunting as they were doing their little bit of work in feeding the boiler. Nothing in the way of a governor would make one of those engines run regularly. The same might also be said, in a less degree, of some of the small engines for other purposes. The suggestion had been made that none of the electrical devices spoken of worked except by a difference in current or electromotive force, and consequently must follow instead of being synchronous with variations of the speed of the engine. One speaker had described two forms of electrical governors, Figs. 18 and 20, which were supposed to overcome this difficulty. As far

Mr. Beaumont. as he could see, these also depended upon a difference in electromotive force or current, and therefore it had to wait until the engine had altered its speed before any effect could be produced upon it. The Author had also suggested that it was necessary that engines should run within 5 per cent. with a load varying 90 per cent., and with a boiler-pressure varying 10 lbs. He should like to ask practical electrical engineers whether it was necessary that engines should be fitted with anything, electrical or mechanical, that would keep them running within 5 per cent. with that fluctuation in speed. The Author appeared to speak as though he meant that the engine was fluctuating constantly within that range of 90 per cent. As far as he knew, no electrical engineer would arrange any installation in such a way that it should be necessary that the governor should be able to keep the engine within 5 per cent. of a normal speed, with a range of working altering 90 per cent. continually. It might be that at one part of the day, or at one part of the period during which lighting was going on, there might be 90 per cent. more work than at another, but the time was generally known to those who had the installation in charge, and to the engine-driver who could regulate the steam-supply accordingly, and it appeared to him that there was no necessity to make the engine in such a way that it should be able to run at a uniform speed with work varying up and down through such an enormous range. But, even if that were so, it was not altogether a question of the governor, but was also a question of the engine. No electrical governor would anticipate alterations of speed in the engine, and he believed that good mechanical governors were made that would work as quickly as any electrical governor yet described; because, although the electrical arrangements acted in less than an assignable length of time, still they had to do so through certain mechanical devices, through details that were connected with other details. The most successful one was worked by a water-piston that was controlled by means of a small equilibrium-valve driven by means of a lever that was actuated by means of something moved up and down by a solenoid. Through those means there would, unless great care was exercised in keeping them in order, be a sufficient loss of time to make the operation slow, or a very little faster than a good high-speed governor acting with an automatic cut-off as described by Mr. Paxman. Unfortunately, the Author had not thought it worth while to give some particulars which would have been of great interest. Referring to governors, he had stated that he had recently heard of a case in which fifty out of two hundred Swan

Mr. Beaumont.

lamps had suddenly broken through the failure of a governor, but he had not stated what the character of the governor was, or the way in which it worked. If he had given that information, electrical engineers might have avoided that kind of governor in the future. He then suggested that an electrical governor was the only thing to be used. Mr. Beaumont did not know that an electrical governor was not the best thing that could be used to govern a dynamo machine; but even suppose there was one satisfactory in every respect for the engine, it might be a question whether a position close to the engine, near oil, steam, dirt and heat, would be a good thing for electrical apparatus. It might also be remarked that, though the Author had heard of a case in which fifty Swan lamps had been destroyed because of the failure of a governor, it was not necessary to condemn all governors, and rush to something electrical, and especially not to such an apparatus as he had described. Mr. Swan had spoken of the economy of electric lighting on board ships, and had referred to engines consuming 2 lbs. of coal per indicated HP. He should like to know whether any of the engines used on board any ship for electric lighting were worked with 2 lbs. of coal. Large screw-engines were worked with that amount of coal, and even less, and Mr. Swan seemed to think that the main engines were driving the dynamo machines. He believed that that was not the case in any of the ships in which electric lighting was used. But if there were engines working with that amount of coal, it would be interesting to know what they were, especially as the Author had, he believed, underrated the consumption of coal by engines generally used on board ship for lighting purposes.

Mr. Hayes.

Mr. JOHN HAYES desired to draw attention to the case of the s.s. "Tilly," built on the Clyde under his supervision, which vessel was equipped with a novel installation of electric-lighting machinery, the principal feature being a powerful submarine lamp, which had been referred to by the Author of the Paper as the only instance known to him of the adaptation of the electric-arc lamp to submarine purposes. The submarine lamp here referred to, and as shown in Fig. 14, was an electric-arc lamp, encased in a glass cylinder 15 inches high and 10 inches in diameter, the joints at both ends being made water-tight; the current was supplied by a Phœnix dynamo, driven direct by a Gwynne "Invincible" high-speed engine, running at six hundred and fifty revolutions per minute, and generating a current of 60 amperes, with an electromotive force of 40 volts, the result being a light of 15,000 candles, with an expenditure of about 4-HP. in

Mr. Hayes. the lamp. At the close of the trial-trip of the "Tilly" on the Clyde, he had the vessel anchored off Greenock, and at once proceeded to test the submarine lamp, by a continuous full-speed run of four hours' duration, the lamp for the whole of this time being illuminated and submerged below the surface of the sea. The effect produced was very striking and beautiful as the darkness of night came on, the four hours' trial being successfully completed at 10 P.M. This powerful submarine lamp and the S.S. "Tilly," intended for fishing purposes out in the Java seas, were the practical outcome of experiments carried out by himself three years ago, when, by means of incandescent lamps, he found that the electric light submerged had a strong attractive influence over fish. The "Tilly," on leaving the Clyde, steamed direct for Batavia, through the Suez Canal.

⁂ The reply of Mr. Jamieson will be found at the end of the Correspondence.

Correspondence.

Mr. Crompton. Mr. R. E. CROMPTON remarked that the question of low speed dynamos for ships had excited the greatest interest amongst the manufacturers of these machines, and great progress had been made. The Author had given little information on this point, stating merely that several of the best forms of dynamo had been modified for ships' use. Up to a recent period, this modification, as usually carried out, consisted in winding on to the armature an increased number of coils, making a large machine do the work of a small one, and certainly this was not a scientific mode of solving the problem. If, when put into the form of a simple formula, where $E_a = \frac{r\,n\,a\,\mu}{1{,}000{,}000}$, E_a being the electromotive force in the armature in volts; r the revolutions per minute; n the number of turns of winding on the armature; a the area of cross section of the armature core; and μ a coefficient which depended on the intensity of the magnetic field through which the turns of wire n passed; evidently, if the revolutions per minute were to be kept small, the requisite E_a would be obtained—

1st. By making a large, and this involved a large and expensive machine.

2nd. By making n large, which meant winding a great number of turns of thin wire on the armature.

Mr. Crompton.

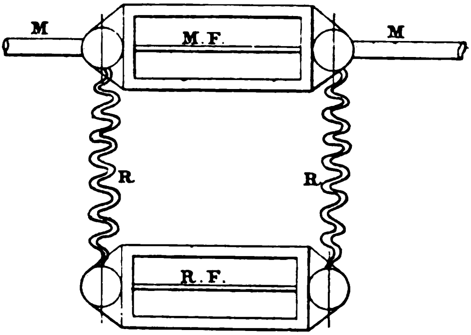
3rd. By making μ large, in other words increasing the strength of the magnetic field.

Now, up to a recent date, whenever sea-going engineers insisted on the revolutions of the dynamos being kept down to five hundred revolutions per minute, so that the dynamos could be coupled direct to the steam-engines which drove them, the first two methods only were employed. It remained for Dr. Hopkinson, and in a lesser degree for himself, to obtain the necessary electromotive force at the required low speed, by increasing the strength of the magnetic field. This had been arrived at by them independently in much the same way, viz., by using, both for field magnets and for the armature core, a greatly increased mass of the softest and purest charcoal iron, and proportioning the parts composing the magnetic circuit so as to obtain the least possible resistance to the passage of the lines of force. This improvement in dynamo apparatus enabled machines to be constructed giving sufficient electromotive force for working the lamps at the comparatively low speed of four hundred revolutions per minute, and still to maintain a high efficiency or high proportion of useful output; whereas by the older plan of increasing the turns on the armature, the efficiency of some of the machines used in the Royal Navy and elsewhere was only as much as 50 or 55 per cent. In the later improved machines the efficiency was as high as 84 per cent. at the same number of revolutions. He did not like to let the Author's electric governor pass unnoticed. It was stated in the Paper that a good electric governor was greatly to be desired, and the Author spoke of attempting to solve the problem, as if it had not been already solved. This was a mistake. Mr. Willans, the inventor of the three-cylinder engine, Mr. Wilson Hartnell, the inventor of the bell-cranked governor, and he had been working jointly at the subject of electrical-governors for a considerable period. Nearly a year ago Mr. Willans succeeded in making an electrical governor which gave all the results which the Author asked for, and this identical governor had, to the best of his belief, been practically working up to the present. Since then they had introduced various improvements, and had forty-six of these governors at work. Two of them were governing the two large engines at the electric station at the Victoria Station of the London, Chatham, and Dover Railway. Each of these governors had the task of governing a compound steam-engine, capable of working up to 350 HP. when fully loaded. It maintained the electromotive force of the entire system nearly constant; in fact, it did not admit of a variation

Mr. Crompton. exceeding 1 per cent., although the load of the engine varied from 50 to 160 HP. in the course of the evening. He did not think that any mechanical governor had ever attained this degree of excellence.

Mr. Dunston. Mr. R. E. DUNSTON observed, that as the uncertainty of the electric light had always been one of the most damaging points urged against it, he was surprised that no mention had been made in the Paper of the possibly disastrous and certainly annoying results which must follow the fusion of a main safety-junction. The arrangement shown by Mr. Hedges had, at all events, the merit of trying to alleviate this evil. This arrangement would prevent a total extinction of light owing to a temporary excess of current in the main, if not caused by short circuits; but it would give no indication that it had been called into action, and so the secondary fuse, of large current capacity, might remain in circuit for a considerable time, during which there would be but little protection against undue heating of the wire. He thought that the arrangement adopted by the "Pilsen" Company, which was not covered by any patent, was more serviceable. It was to place in parallel circuit with the safety-fuse a suitable resistance in series with a second safety-fuse. In the annexed diagram (Fig. 24), M represented the main; M F, the fuse in series with the main; R the resistance in parallel circuit with the main fuse; and R F the fuse in series with this resistance. With this arrangement, as with that of Mr. Hedges, both fuses would act in the event of a dangerous short circuit; but should the main fuse fail owing to a temporary excess of current, then the resistance R, suitably adjusted to the circumstances, would tone down the lamps to half

FIG. 24.



PILSEN LIGHT. ARRANGEMENT OF SAFETY FUZE.

power, thereby attracting the attention of the attendant, and ensuring the renewal of the main fuse. With regard to the sectional area of copper required in leads, and the amount of insulation desirable to place thereon, he should be sorry to advocate false economy; but on the other hand he must enter a protest against rule of thumb. It had been urged that the cost of copper was, relatively to efficiency, but a trifle. To this he dissented for two reasons: first, it was incorrect; secondly, it might have a tendency to check investigation on this important subject, and to cause practical men to revert to the rough rule—"Have copper enough"—from which they were only now beginning to be free. Mr. Dunston.

Mr. J. F. Flannery submitted the particulars of the cost of electric lighting on the Birkenhead steamers, upon the basis of which the system was being fitted by the Wallasey Local Board to two saloon river passenger-steamers being built at Preston. The vessels were 130 feet long, 35 feet beam, and had about twenty-five Edison-Swan lamps. In the case of one vessel, the dynamos were driven by Mather and Platt's horizontal engine costing £240, and in the other by Parker and Elwell's 3-cylinder engine, costing £180. The lamps were guaranteed to last one thousand hours each. The total cost of coal on one steamer for nine hundred and twenty hours was 1½*d.* per hour, and oil for the engines came to about 2*s.* 6*d.* per week. The cost of the oil and wicks of the old oil lamps was £17 per annum for each boat, and the cost of electric lighting was about £40 per annum for coal and oil; but there was of course no comparison in the amount of illumination, nor as to the general appearance of the saloons under the two systems. It was estimated by the engineer-in-chief of the Guion line that the expense of the electric-lighting system was, for maintenance and consumption, about three times as much per vessel as the former system of oil lamps. Mr. Flannery.

Professor G. Forbes observed that the defect of the lamps often going out, when the ship rolled heavily, was due to the spring by which the lamps were attached to the terminals. If the steward in fixing a new lamp did not take care that the pressure of the spring was equable, a heavy roll of the ship overcame the spring and broke temporarily the electric circuit. He lately noticed the same effect in his own cabin on the "Servia," and the steward was alone to blame. Makers of lamps, however, might take note of the trouble, and arrange matters so that not even the steward could cause this annoyance. Professor Forbes.

Mr. W. A. Gorman remarked that the Author, in concluding the Mr. Gorman.

Mr. Gorman. Paper, mentioned as a novelty the electric light for fishing and submarine purposes. But since 1870, in conjunction with Messrs. Siemens, Messrs. Siebe and Gorman had manufactured submarine electric lamps.[1] In the hands of inexperienced men the arc light was not so suitable as a lamp now constructed by them. It consisted of five Swan glow-lights, placed in a glass globe made of sufficient strength to withstand the pressure of water. The globe was held in metal flanges; the top flange contained the stuffing-box for the wires, sling handle and weight. The total cost was only £6. Electric light was most valuable for submarine work. A large steamer had been saved in November, 1884, entirely through the divers having a submarine electrical lamp. The work was carried out day and night, and the vessel was floated just before a heavy gale came on. He considered electric light for submarine purposes to be most valuable, and with the aid of the telephone a great assistance to divers when engaged in harbours, or when working in the holds of sunken ships, as also for holding a survey upon a vessel damaged under the water line, frequently obviating the expense of docking.

Mr. Hall. Mr. C. Hall, of the Peninsular and Oriental Steam Navigation Co., was enabled, by favour of the Directors, to submit the following statement of that Company's experience of the cost of electric light on board ship. He should premise that the statement made by Mr. Farquharson, with reference to the comparative cost of the two systems on board the "Crocodile," appeared to be incorrect in one important particular; he referred to the depreciation of electric plant. By allowing only 2½ per cent. Mr. Farquharson estimated the "life" of the plant at forty years; but he was much mistaken if ten years' life was not a more trustworthy estimate, looking at the likelihood that all existing plant would be obsolete ten years hence. He had, therefore, reckoned 10 per cent. depreciation on plant, and 5 per cent. on the foundations; while a similar depreciation of 10 per cent. had been allowed for the oil lamps. The electrically lighted ship "Valetta" had been running for nine months, covering during that period nearly 42,000 miles. Her actual cost for lighting was equivalent to the following amounts for a complete year:—

	£.	s.	d.
Coal, oil, stores, candles, repairs, lamp renewals, pay and victualling of men	664	7	2
Depreciation of plant at 10 per cent., of foundation 5 per cent. . . .	179	5	0
	843	12	2

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[1] Minutes of Proceedings Inst. C.E., vol. lii., p. 85.

Mr. Hall.

In comparison with this he had caused an account to be prepared of the cost of ordinary lighting on board the "Carthage," a ship of similar type and size, employed on the same East Indian and Australian service.

	£.	s.	d.
For one year the cost of lighting by oil and candles (including repairs of lamps) was	493	13	7
Add 10 per cent. depreciation of lamps	70	0	0
	563	13	7

It would thus be seen that the result was different from that obtained on board the "Crocodile," where an economy of about £300 a year had resulted from the use of electric light. In the "Valetta" there was a loss of £279 18s. 7*d*. or 49½ per cent. This was not difficult to explain, the fact being that the "Carthage" and other Peninsular and Oriental steamers were very economically lighted by means of a mineral oil, which was both safe and cheap. The "Crocodile" on the contrary appeared to have been lighted in an expensive way by olive or colza oil and candles. It should be stated that although there were two hundred and fifty electric lamps on board the "Valetta," she was not exclusively lighted by electricity; oil lamps were still used by the trimmers in the bunkers, and for cargo purposes in the holds. Some candles were also burned in the officers' cabins, &c., when the ship was lying in port without passengers, it being undesirable to keep steam at such times for the electric light.

On board the "Valetta" was the only specimen which the Peninsular and Oriental Company had of the double-wire system; and it was somewhat curious that she was the only ship in which he had had a case of a cable corroding through the action of salt water. The Author seemed to think this defect a special peculiarity of the single-wire system; but he could assure him that his observation, so far, led to precisely the opposite view. He had adopted the single-wire system with considerable hesitation, the joints between the lamp wires and the skin of the ship being a matter of some anxiety; but his apprehensions on this point had been completely set at rest by the careful way in which these joints had been made by Messrs. Siemens Bros. and Co. He did not share the impression that there was of necessity an increased chance of short circuiting, when the single-wire system was used. But, on the contrary, it appeared to him that the single-wire system, if properly carried out, was less liable to short circuit than the double system. It was scarcely necessary to point

Mr. Hall. out the advantage of having only one wire to deal with and protect instead of two wires, and the additional gain in the matter of diminished resistance was by no means to be despised. Some fears had arisen at first in the minds of the nautical staff that the compasses would be affected by taking the return through the ship; but after careful and prolonged observation, it had been proved that such fears were groundless. The frictional driving-gear of Mr. Raworth had been shown to him on board the "City of Chicago" about twelve months ago, and it at once took his fancy. Four sets were now at work on board ships belonging to the Peninsular and Oriental Company, and the results had been so satisfactory, that similar gear would shortly be fitted to several others. The gear was evidently inferior to none in compactness and simplicity; but its greatest recommendation was the way in which the ship's engineers approved of it. Many other small engines were in use on board for various purposes, of the same type as the engine used by Raworth, and the knowledge that these little engines could be, and in fact were, worked from year's end to year's end with little attention, and next to no repairs, enabled duplicate plant to be confidently dispensed with; a few spare parts, including an extra armature, being the only duplication found necessary. The pulleys were solid blocks of paper, made of a pile of sheets, compressed by hydraulic power, and bolted between two wrought-iron flanges. The paper surface was turned up in a lathe like a block of hard wood, and it was so solid that it rung like a piece of metal when struck. He had not yet been able to detect the slightest signs of wear in any of the pulleys under his charge. He had made it a rule to provide a large margin of power in all the installations for which he was responsible; unless this was done, the engine could not perform its work when the piston became leaky, or other derangements incidental to a long voyage occurred. In many cases it seemed as if there was an undefined idea among electricians, that Mr. Preece's proposal to make a HP. equal to 1,000 watts had become an accomplished fact; but his own practice in this respect was so to proportion the engine, that not more than 400 watts per actual HP. should be expected when new. He could not say much at present with reference to the life of the incandescent lamps on board ship; the oldest lamp afloat, of which he had experience, being only about twelve hundred hours, but the satisfactory duration of lamps in the Royal Navy would solace the gloomy feelings hitherto inspired by the bills for Swan and Edison lamps. No doubt it would soon come to pass that a Swan lamp would be guaranteed for one thousand hours, and replaced gratis if it broke sooner. He must confess, however, that in this respect the Swan lamps had not given much cause for complaint, so far as the Peninsular and Oriental Company was concerned. One vessel had just completed a voyage to China and back with only twenty broken lamps out of two hundred and fifty, but the Edison lamps had not been so fortunate. He had had trouble when the plaster became wet, as it often did in the engine-room or stoke-hole; the little copper wires which passed through it corroded and parted. However, most of the failures of the Edison lamp left the filaments intact, and it had been possible to cobble up the lamps, and make use of them in many cases. In compliance with urgent demands for deck cargo lights, he had reluctantly been compelled to provide them. The prospect of flexible cables bundled about on deck at the mercy of seamen and stevedores was one which he could not contemplate without misgiving, and he should be thankful for a good practical suggestion for a method of keeping these cables out of harm's way. He considered arc lights to be unsuited for passenger-steamers, where it was impossible to give them the same attention as in the Navy. Passenger-steamers could not afford to carry a special officer to look after them, and they would soon be destroyed by the combined effect of coal-dust, steam, salt spray, and the rough handling of unskilled men. He had, therefore, contrived a special form of deck lantern to contain three 40-candle Swan lamps. This lantern served for use at the hatchways, at the yard-arms for coaling; and he had suggested its adoption for dances or entertainments on the quarter deck. Mr. Hall.

For the last two years a good deal of his time, attention, and patience had been absorbed by the care of a large set of storage cells, used for lighting the Company's office in Leadenhall Street. The convenience of the system was of course great; light was available at any moment, day or night, irrespective of engine or engine-driver. Every lamp could be switched into circuit whenever wanted, and put out when done with; the latter operation was, he regretted to say, often forgotten. The service of light had never been interrupted for a single day, but this result had been only obtained by an amount of care and watchfulness which could not be expected on board ship. Another objection to storage cells at sea was the quantity of sulphuric acid carried in them; and the danger to an iron or steel ship from the slopping about of this acid needed no comment. The Author seemed to have a high opinion of the value of insulation-tests, and he agreed with him that they should be made if the installation was taken at a low price, or was

Mr. Hall. in any way doubtful; but such tests were troublesome to make, and for all practical purposes he thought they might be dispensed with, when there was no doubt in the first place that the quality of the cable used was first-class; and in the second place, that the contractors were thoroughly good and responsible people. The contractor would protect himself by employing only good and capable men, if he knew that he would have to make good defects. After all, there was no insulation-test so thoroughly searching as practical work at sea for a couple of long voyages. He agreed with the Author that a perfect mechanical governor for sea-going electric-light engines did not exist; in fact, the present governors were not much used; they caused the light to fluctuate, and the men preferred to work by hand, keeping the governor adjusted to check any large increase of speed, such as would occur if a whole circuit of lamps went out simultaneously. He feared that even the electric governor shown by the Author would scarcely overcome the difficulty, seeing that it merely governed the steam-supply. Now electrical engines were connected to exhaust into the main condenser at sea, and ran with the regulation open, perhaps, half a turn; the work being mostly done by the vacuum, and it must be evident that, unless the throttle was absolutely steam-tight, the engine would run on the vacuum for some time after the throttle was closed. It was undesirable to put a second throttle into the exhaust, and govern at both ends; but he thought it was possible that something might be done by employing the governor to brake the engines.

Mr. Halpin. Mr. Druitt Halpin remarked that the question as to the consumption of steam in small direct-acting engines having arisen, it might be of interest to give particulars of a test lately undertaken in America with a Westinghouse engine, and published by the "American Machinist," 29th November, 1884. The engine had two single-acting cylinders, each 7 inches in diameter, by 7 inches length of stroke, and made two hundred and ninety-three revolutions per minute, the steam being cut off at half stroke by the lap of the valve. The boiler-pressure was 95 lbs. per square inch, and the clearance 7·2 per cent. The mean effective pressure was 44·13 lbs., and the indicated HP. 17·54; the brake HP. being 15·53, or an efficiency of 85 per cent. The steam used per indicated HP. per hour was 34·36 lbs., and per brake HP. 38·8 lbs. Of the water used, 80 per cent. was accounted for by the indicator. The grate area was 4·9 square feet, and the heating surface 80·6 square feet. The evaporation to and from 212° Fahrenheit was 9·44 lbs. of water per lb. of coal, and, taking the temperature of the feed at 56° Fahrenheit, this gave a consumption of 5 lbs. of coal per indicated HP. per hour. With reference to the question of regularity of running of engines driving dynamos, he thought mechanical engineers were often most unjustly blamed by electrical engineers for faults which really did not exist. He had lately seen an installation consisting of several large arc lamps driven from one engine, and he observed that the irregularity in the light took place in each lamp successively. As they were all driven by the same engine, this could not possibly have happened had the driving of the engine been at fault. Mr. Halpin.

Mr. W. H. MASSEY observed that, although it was the fashion to solder joints, he had found it easier and better in every way to make tight well-bound joints without solder. Copper being such a good conductor of heat, when soldering was resorted to, the insulating material on the cable or lead was spoiled for a longer distance on each side of a large joint than was allowed for in ordinary practice; besides which there was always a much greater chance of injurious matter getting into the joint, even when the use of "killed salts" was forbidden, and so causing chemical action. He had known cases where, after passing a strong current through a circuit for a short time, a kind of secondary-battery action could be detected at the joints; and yet these joints and the insulation of leads had been tested, and pronounced very good. What might do very well for submarine cables, would not answer for electric-light joints, because there might be more electro-chemical action during five minutes with the latter than would take place with the former in ten years. He thought it desirable to make some tests, but his experience had been that too much testing made men engaged in jointing careless. In his opinion, it was far more important to establish an insulation that would last well, than to aim at absolute perfection in the first instance. He had been on board ships fitted up by eminent firms, and where the total insulation-resistance was not more than two or three times the resistance of an incandescent lamp; and, although less than he should insist on for his own work, these installations might possibly outlast some of those fitted out under the Author's rules. Mr. Massey.

Mr. J. MUNRO said that it was beginning to be recognised that the use of the arc light at sea, or for lighthouse purposes, was subject to a serious drawback, namely, its weak penetrative power in foggy or misty weather. Recent experiments at the South Foreland had confirmed this fact, which many electric-light engineers had before observed. A slight mist reduced the intensity of Mr. Munro.

Mr. Munro. an arc light in a remarkable manner; oil and the incandescent electric light were not subject to this great reduction. He attributed the reduction to the arc light being comparatively poor in penetrative rays. The atmosphere allowed certain rays of the spectrum between B and δ to pass more freely than other rays. From the red to the yellow, including the orange, was the most penetrative part of the spectrum. Now it was in these orange rays that the arc light was deficient, as compared with other lights; whereas it was rich in blue rays, which were readily absorbed by the atmosphere. How then could the defect be remedied, and more value for search- and lighthouse-purposes be added to this powerful source of light? Obviously the direct method was to supply the rays which were wanting. Carbons, prepared with slight admixtures of salts, such as sodium salts, giving red, orange, and yellow rays, ought to be tried instead of the ordinary carbons. Again, the incandescent lamp, having a yellowish colour, was more penetrative than the arc in misty weather. It was therefore advisable to arrange the electric plant so that incandescent lamps could be quickly substituted in the lighthouses for the arc in foggy weather.

Mr. Phillips. Mr. C. H. Phillips would specially emphasize the Author's contention that every installation should be tested and passed by competent electricians, and with such conditions he believed the supervision might be fairly entrusted to the engineer on watch: the Author had judicially stated the "for and against" wiring with one lead or two leads; and if he preferred the one-wire system, making the iron of the ship earth, he slightly differed with him. As a matter of cost he thought the extra wooden and water-proof casing throughout would more than counterbalance the slight cost and advantage of return wires. He agreed with him that it was most essential to have an ample carrying capacity in the leads, and that for all ordinary lengths on board ship the standard of 1,000 amperes per square inch of copper was sufficient. There had been some difficulty in finding a dielectric to cover all the requirements stipulated for by the Author, but he thought they had now been fairly met by the use of high-class vulcanized india-rubber where gutta-percha was almost useless, as it would not stand exposure to the atmosphere. He felt sure the Author would agree with him that considerable skill and care were required in running the leads, as they were far more liable to damage on board ship than on shore. The idea of testing "air leading wires" in salt water, after twenty-four hours' submersion, was a great innovation upon the empirical ways in which too many installations had led to failure.

Mr. Jamieson.

Mr. A. JAMIESON, in reply to the discussion and correspondence, said he agreed with Dr. Hopkinson that if the absolute insulation-resistance of dynamos was carried out in inverse proportion to their size or conductor-surfaces, an equal degree of efficiency and safety would result; and he would therefore modify his rather hard-and-fast rule, thus:—"New dynamos for one hundred incandescent lamps to be tested immediately after a run of not less than one hour at full power, and to have an insulation-resistance of not less than 10,000 ohms per volt generated by them, between the metal frame-work and the armature with electro-magnet coils in circuit, as well as between the series and shunt wires of the electro-magnets. The insulation-resistance of other sizes to be in inverse proportion to the number of lamps they work, *e.g.* a two-hundred-light dynamo to have 5,000 ohms per volt generated under the above circumstances." He had found by experience that it was advisable in electrical work, not to state vaguely that the insulation-resistance was to be "good," or "perfect," as these words were variously interpreted, but rather to fix upon an amount of insulation which could be attained in practice with due precautions, and which would at the same time ensure a good margin for deterioration. Great care should be taken that all crevices, corners, and surfaces between the conductor and the cores, or frame work, should be filled up with some good insulating substance impervious to damp, such as vulcanized fibre and Scott's insulating varnish, to prevent as far as possible the lodgement of damp from steam, water, as well as oil and dirt, which, more especially on board ship, sooner or later find out weak points in the dielectric, and had so frequently given trouble. He had found it necessary in certain instances to cover in the dynamo with a metal casing to prevent the water from main engine-cranks splashing over it, and thus destroying the insulation.

In a similar way the rule stated by the Author for the absolute insulation-resistance of the leading wires, &c., might be thus modified:—"The insulation-resistance of each set of circuits amounting to one hundred lamps, including the switches and cut-outs, to be not less than 1,000 ohms per volt generated by the dynamo at the normal speed.[1] The insulation-resistance for any other number of lamps to be in inverse proportion to the above amount; *e.g.* the whole of the leading-wire circuits put together for a ship having two hundred lamps to have not less than 500 ohms per volt." As instances that there was no difficulty in surpassing

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[1] Equivalent to 10 megohms per lamp of 100 volts.

Mr. Jamieson. the above requirements, he had found, in taking final tests on a damp day on board the s.s. "Arawa," where there were three hundred (100-volt) lamps, that the absolute insulation-resistance of the whole leading-wire system throughout the ship, including the branch and single switches, &c. (lamps left out), amounted to 102,500 ohms, or 30·75 megohms per lamp; and the copper resistance of the longest section on board from the dynamo to the furthest lamp was only 0·29 ohm.[1] The above results were accomplished by care in the fitting and jointing on the part of Messrs. William Denny and Brothers electrical staff, and by using first-class material throughout, and applying frequent searching electrical tests during the insertion of the wires and fittings, without which in the Author's opinion good and lasting work could not be always obtained.

It might be mentioned that the contractors for the wire will guarantee an insulation-resistance of 100 megohms per 1,000 yards for the class of wire used in this instance (viz. best vulcanized india-rubber covered wire, type D), after twenty-four hours' immersion in salt water at 60° Fahrenheit. This wire would suit Mr. Albright's requirements for masthead lights, and if properly embedded in deeply grooved wooden casings well covered with the putty white-lead composition mentioned by Mr. Farquharson, and wooden tops to the casings, it should withstand all the trying effects of the stokehole.

The Author was glad to find from the remarks of Mr. Preece, Mr. Swan, Mr. Phillips and others, that the necessity for good insulation in electric-light systems was beginning to be generally appreciated, as from his early training in connection with submarine cables he had been one of its first and strongest advocates. No doubt, as Mr. Hall remarked, practical work at sea for a couple of long voyages was a thorough test of insulation; but what firm would wait for such a long and protracted test as that if, by the application of proper appliances and rules, the value of the materials and of the installation generally could be determined before the vessel started on her first voyage.

In regard to the several opinions expressed about the size of conductors which he had proposed, the adoption of a larger cross area would in no way lessen the necessity for an equally good quality and thickness of dielectric, the electromotive force being

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[1] Final tests of s.s. "Tainui" before leaving London for New Zealand, with all switches and cut-outs in circuit, gave I.-R. of 14·75 megohms per lamp, and a mean C.-R. of 0·28 ohm per circuit. Jan. 26, 1885.

Mr. Jamieson.

the same, and consequently the first cost and expense of fitting up larger leads would be in a greater ratio than the increased size of conductor. The sizes adopted by him were larger than most contractors had been in the habit of using. The rise of temperature above surroundings due to electrical heating was, even for the largest wires required, under 10° Fahrenheit. The fall in potential along 100 yards of the conductor was only 2·5 volts with the full normal current, and as the leading wires were seldom of that length, except to the forecastle and steerage, or second-class passengers' quarters, the slight difference between the light of lamps closer to the dynamos and those at the further places was not so much as that due to the discrepancy between the lamps themselves, as pointed out by Mr. Siemens in reply to Mr. Preece.

The rise in potential, when all the lamps but one of a section were turned out, under the circumstances mentioned by Professor Perry, only affected the lamps in proportion to their distance from the dynamo, and for the above mentioned reasons it was not worth while in the case of ships to prevent it "by lavishness in the cost of the copper cable." The percentage waste of energy, due to the heating of the conductor, was only 2·6 per cent. of the power being conveyed by the conductor for every 100 yards of its length. The annual cost of power wasted in heating the conductor at £10 per I.HP. balanced the yearly interest at 5 per cent. on the prime cost, plus depreciation at 5 per cent., plus interest at 5 per cent. for the best class of vulcanized india-rubber covered copper conductors, in the case of a ship trading between England and India. The Author's rule and table fitted in well with the usual sizes kept in stock by manufacturers, and with the most approved method of grouping the sections under the control of main switches into twenty and twenty-five lamps, as well as for subjections into ten lamps or less. In very large ships with leads over 100 yards in length and for the double-wire system, the sizes might advantageously be increased to 1 square millimetre per ampere instead of 1½ ampere, but in no case was there any necessity for going beyond this on board ship.

In reply to Mr. Mance as to whether the one hundred and fifty ships already fitted with the electric-light still used it, he had only heard of one case in which it had been discontinued, and that was where the attempt was made to drive the dynamos direct from the marine engines. The general tendency was rather to extend it in those ships which had only at first been partially lighted. In electric lighting, the unit of length fell from knots to

Mr. Jamieson. yards, and the estimate of insulation-resistance correspondingly fell from megohms to ohms! The joints mentioned by Mr. Mance were the best for electric-lighting, and were those which the Author had insisted upon in his specifications.[1]

The balance sheets and statements made by Messrs. Farquharson, Hall, and Flannery, respecting the cost and up-keep, as well as life of, incandescent lamps on board ship were most interesting and instructive. The estimate by the engineer-in-chief of the Guion line that the cost of the electric-light system for maintenance and consumption was about three times as much per vessel as the former system of oil-lamps, could only be accounted for on the assumption that that well-known line was sparely supplied with oil-lamps and lavishly supplied with the electric light, and was now making up for former deficiencies. Mr. Hall had apparently omitted to add the pay and victualling of men attending to oil-lamps and candles, which would make the difference between the two systems of lighting still less in the cases quoted by him. No one gave the first cost of a complete installation. He had found that lately an installation on the double-wire system with direct driven dynamos at five hundred revolutions per minute, costs on an average for fifty lamps £400, for one hundred lamps £700, for two hundred lamps £1,200, and for three hundred lamps £1,500. On the single-wire system the estimate was 5 to 10 per cent. cheaper, and with leave to run the dynamos at one thousand revolutions or more per minute, and any ordinary vertical or horizontal engine, the estimate was 10 per cent. cheaper still. No doubt these prices would be still further reduced, for they had been much higher in the beginning of this rapidly progressing industry. Of course it must be borne in mind that the above estimates were only for plain durable fittings, and did not refer to highly artistic chandeliers, or heavily gilt or electro-plated brackets.

The battle of the "single-wire" *versus* the "double-wire" system had been so well fought, that the Author felt he could not do better than refer the advocates of the latter system to Mr. Hall's practical remarks in the Correspondence. An equal number of ships had been fitted, under the Author's inspection, on both systems, and he was bound to confess that when the work was thoroughly well done throughout, and the dynamos thoroughly

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[1] Forty-six secondary cells had been fitted on board the s.s. "Olympo," bound for the River Plate, by Messrs. Harvie, Glasgow, November 1884. This experiment had not had a sufficiently long trial to warrant an opinion being expressed as to their suitability for ship use.

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well insulated internally, and if possible from the earth, the single-wire system was the cheapest, the simplest, and the best on board ship. As regards the facility for accurately localizing the position of faults, with the meagre testing appliances usually placed on board ship, the one system afforded no advantages over the other. The only warning that the attendant had in either case was the giving way of a fusible wire or cut-out; and if these were judiciously arranged in each section and sub-section, and, if preferred, at each lamp as well as in the dynamo itself, there need be no fear of any serious break-down for more than a few minutes.

In regard to joints, he was astonished to find Mr. Massey asserting that "he had found it easier and better in every way to make tight, well-bound joints without solder." He would, no doubt, find it easier, but certainly not better. The Author could point to an instance in which "bound joints" had cost a contractor a very large sum of money to replace by well-soldered joints, Joints should not be soldered with "killed salts," but with rosin, for if killed salts were used, the whole of the joints would, to a certainty, give way by being eaten through in a short time, as in the case of a ship not very long ago. He would point out to Mr. Massey that the perfect success in submarine-cable jointing had been only arrived at by a constant supervision over the jointer's work by the electrician, and by every joint in the factory being duly and severely tested, and a record kept of its condition and position. In the same way, workmen could only be trained to make electric-light joints thoroughly, by the electrician in charge seeing to, and even testing every joint, until he could place implicit confidence in the jointer; in fact, electric-light joints had to be better made, if such were possible as far as metallic contact was concerned, for the very reasons advocated by Mr. Massey. There was no difficulty in soldering a wire capable of carrying 100 amperes or more, if done in the proper way.

In respect of governors, the Author would refer Mr. Paxman, Mr. Beaumont, and Mr. Oughterson to the remarks of Mr. Hedges, Mr. Crompton, and Mr. Hall. He would draw Mr. Beaumont's attention to the fact that if the main cut-out fused, or the main switch was turned off, the whole working load was instantly thrown off the engine; and that a difference of 5 per cent. in the speed meant a great difference in the electromotive force and the light. He had to a certain extent misinterpreted the action of his electric governor; what it aimed at was to keep the E.M.F. constant at the terminals of the dynamo. In answer to Mr. Mordey, the copper disk of his governor had been made over

Mr. Jamieson. $\frac{1}{4}$ inch in thickness, to avoid as far as possible the action he feared. He was glad to learn that mechanical governors were made to keep the speed uniform within 2 per cent.

The remarks of Mr. Hall as to the ship compasses being unaffected by the strong currents passing through the electric-light cables would satisfy Mr. Joel's theoretical fears. The explanation was this: the wires being underneath the iron or steel decks, the magnetic effects were shielded from the compasses placed above deck, in the same way that the delicate magnets inside Sir William Thomson's marine iron-clad galvanometer were shielded from outside magnetic influences. Due precautions were taken to keep the wires sufficiently far away from the compass, if at any time they had to be brought up above deck.

Now that dynamos were made much superior to those manufactured a few years ago, the break-downs on board ship were mostly due to the engines; and those whose business it was to furnish electric-light engines for ship use should adopt every precaution to prevent this by making them extra strong in all the working parts, and as simple, accessible, and durable as possible, with self-lubricating connections to all the bearings from one or two common centres, capable of holding a supply of oil for three or four hours' consumption. Economy of steam was not of so much importance as durability and capability of working with a minimum of attention, combined with economy of oil. Mr. Swan would have been nearer the average consumption of coal for ship electric-light engines if he had said 5 lbs. of coal per hour per indicated HP., instead of only 2 lbs.

The words "nominal HP." had been quoted by Mr. Preece in describing the lighting of the "Aurania." What was nominal HP.? —nominally anything; and it showed the absurdity of engine-makers using this antiquated and misleading expression. Engineers should always state the indicated HP., or better, effective-brake HP., with such and such steam-pressure and speed.

Several of the speakers misinterpreted his remarks regarding the placing of dynamos. What he said was that "the plane of rotation should be athwartship;" in other words, the dynamo-spindle should be fore and aft, which bore out the effects mentioned by them.

He had been blamed for having treated the subject of the Paper in too general a way, and for not giving sufficient details of what he had done. When the members came to examine the various detail drawings with a self-explanatory index attached to each, and to consider the large amount of useful practical matter that had been elicited by the discussion and correspondence, he was fain to hope that they would credit him with having adopted the best plan under the present daily improving condition of this branch of electric lighting. Mr Jamieson.

18 November, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair;

and 25 November, 1884.

Sir FREDERICK J. BRAMWELL, F.R.S., Vice-President,
in the Chair.

The discussion upon the Paper on "Electric Lighting for Steamships," by Mr. Jamieson, occupied both evenings.

2 December, 1884.

SIR J. W. BAZALGETTE, C.B., President, in the Chair.

THE following Associate Members have been transferred to the class of

Members.

GUYBON DAMANT ATHERSTONE.
GEORGE BURTON CHADWICK.
HENRY TANNER FERGUSON.
BENNETT FITCH.
JOHN BAILLIE HENDERSON.
ALEXANDER WILLIAM JARDINE.
HENRY KEMP.
EDWARD JAMES MOORE.
JOAQUIM GALDINO PIMENTEL.
EDMUND WALTER PLUNKETT.
FREDERICK STAFFORD.
GEORGE HENRY STAYTON.

The following Candidates have been admitted as

Students.

WILLIAM ALEXANDER.
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CLARENCE CRAIG.
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JOHN DAVY.
ALBERT DENISON.
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LAWRENCE GIBBS.
HENRY JESSE GOOCH.
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CHOSAKU YOSHIMURA.

The following Candidates were balloted for and duly elected as

Members.

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CHARLES JOHN BOND.
ARCHIBALD CONSTABLE.
ELMER LAURENCE CORTHELL, M.A.
SCROPE BERDMORE DOIG.
ERASMUS HENRY MAURITIUS GOWER.
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JOHN THOMAS KEY.
JAMES MURDOCH NAPIER.
HARRY GEORGE PALLISER.
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WILLIAM SMITH.
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THOMAS ANDERSON.
LAWRENCE HENNESSEY CLUBBY ARMSTRONG.
GEORGE IDEN AUSTEN, Stud. Inst. C.E.
THOMAS RICHARD BAYLISS.
JAMES FETTES BOULTON, Stud. Inst. C.E.
FRANCIS BOYNTON, Stud. Inst. C.E.
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JAMES BEAUMONT BUCHANAN.
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DAVID JOHN RUSSELL DUNCAN.
DAVID THOMAS FENDER.
JOHN COLEMAN FERGUSSON.
EDUARDO DE MORAES GOMES FERREIRA, Stud. Inst. C.E.
GEORGE SEPTIMUS FIRTH, Stud. Inst. C.E.

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Frederic Gleadow, Stud. Inst. C.E.
Percy Murly Gotto, Stud. Inst. C.E.
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Henry William Hargrave, Stud. Inst. C.E.
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Cosmo Charles Hooley.
John Isidor de Jongh.
Algernon Leventhorpe.
Graham Rigby Lynn.
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Joseph Thomas Pullon.
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Thomas Harman Tyndall.
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Leonard Wigan.
William Wood, Stud. Inst. C.E.
Alfred Woodhouse.
Oswald Vavasour Yates.

Associates.

David Doig.
Alfred Lass.
Donald Nicoll.
Captain George Charles Parker.
Frederic Charles Rowan.
William Watson.

(*Paper No. 1990.*)

"The Working of Tramways by Steam."

By the Hon. Richard Clere Parsons, B.A., B.C.E. Dublin, M. Inst. C.E.

For many years, indeed since the time Blenkinsop ran his first locomotive engine on a tramway near Leeds, efforts have been made to work traffic along country roads and streets of towns by means of steam-power, and thus save the great expense of horses where heavy loads have to be transported. Road locomotives of various kinds have been invented from time to time, an example of which is shown in Plate 4, Fig. 1; but none, however, have proved in all respects successful, owing to the great resistance to heavy machines, such as traction-engines, moving along ordinary macadamized roads. Another difficulty, which has prevented this form of locomotion from being promoted with greater zeal, has been the restrictions imposed by the Acts of Parliament passed in the years 1861 and 1865, which stipulated that a speed of 4 miles an hour should not be exceeded, and that a man carrying a red flag should go in front of the engine to warn the public of its approach. With these restrictions in force, it is evident that to carry omnibus traffic by steam on ordinary roads would be unprofitable, and the Author knows of more than one instance where efforts of this kind have been frustrated on this account.

In the year 1870 the first Act was passed which enabled tramways to be constructed along the public roads and highways, a practice which at that time was largely adopted in America. In the same year the Board of Trade was invested with ample powers to regulate both their construction and their working, and in the year 1875 steam was permitted to be used subject to the following very strict regulations:—

REQUIREMENTS.

The engine to be used on the tramways shall be an engine built by Messrs. and Company, of , and designated by a plate affixed thereto as "No. 1," if, and so long as it complies with the following requirements, that is to say:—

(a) It shall be fitted with an efficient brake, and a governor shall be attached to the engine, so arranged that at any time when the engine attains a speed of 10 or more miles an hour, it shall cause the steam to be shut off and the brakes applied.

(b) The number shall be shown in a conspicuous part thereof.

(c) It shall be fitted with an indicator by means of which the speed is shown; with a suitable fender to push aside obstructions; and with a special bell to be sounded as a warning when necessary.

(d) Arrangements shall be made enabling the driver to command the fullest possible view of the road before him.

(e) It shall be free from noise produced by blast or clatter of machinery. The machinery shall be concealed from view at all points above 4 inches from the level of the rails, and all fire used on the engine shall be concealed from view.

Every carriage used on the tramways shall be so constructed as to provide for the safety of passengers, and for their safe entrance to, exit from, and accommodation in such carriage, and for their protection from the machinery of any engine used for drawing or propelling such carriage.

REGULATIONS.

1. The speed at which the engine and carriages shall be driven or propelled along the tramways shall not exceed the rate of 8 miles an hour, and the speed

at which such engine shall pass through movable facing points shall not exceed the rate of 4 miles an hour.

2. The special bell shall be sounded by the driver of the engine, from time to time, when it is necessary as a warning.

3. No steam or smoke shall be emitted from the engine, and no hot air shall issue in a way to annoy passengers.

4. Whenever it is necessary to prevent impending danger the engine shall be brought to a standstill.

5. The entrance to and exit from the carriages shall be by the hindermost or conductor's platform.

6. The brakes attached to the carriages shall be under the control of the driver of the engine.

7. The Company shall place and keep placed in a conspicuous position inside of each carriage in use on the tramways a printed copy of these requirements and regulations.

8. For any breach of any of the above requirements or regulations, the Company shall, for each offence, be liable to a penalty not exceeding £10.

CONDITIONS.

The Board of Trade and their officers may, from time to time, and shall on the application of the local authority of any of the districts through which the said tramways pass, inspect the engine or carriages used on the tramways, and the machinery therein, and may whenever they think fit prohibit the use on the tramways of any of them, which, in their opinion, are not safe for use.

Signed by order of the Board of Trade, this fourteenth day of June, 1875.

HENRY G. CALCRAFT,
An Assistant Secretary to the Board of Trade.

In order further to facilitate the introduction of mechanical power, the Board of Trade decided to grant two licences of six months each, to enable any company to carry out experiments on lines already constructed, and thus obviate the necessity of obtaining a new Act sanctioning the use of steam, until it had been proved that the introduction of this form of mechanical power would be a success.

Shortly after the Board of Trade issued these rules, several tramway companies, having obtained permission from the local authorities, applied and obtained either a fresh Act, or, in the first instance, a steam licence; and in 1878 fourteen engines were plying on tramways in the United Kingdom. Among the earliest to take up steam was the Vale of Clyde Tramways Company, whose traffic was first worked by contract with engines constructed by Mr. Hughes, of Loughborough, from 1878 to September 1881, at which date Messrs. Kitson and Co. constructed eight engines for the company. These have worked most satisfactorily ever since.

At first the six months' licence was of considerable advantage; but now, as a rule, companies who are anxious to adopt steam, apply at once for a special Act of Parliament. Since 1881, owing in a great measure to the success which attended the introduction of locomotives on the Vale of Clyde Tramways, various companies have adopted steam in preference to horses, and a few have substituted it in place of them. Amongst the latter may be mentioned the Leeds Tramway Company, who, after computing most carefully the various items of expenditure connected with horse-traction, and also having made exhaustive experiments with different kinds of motors, have decided to adopt engines similar to that which will be described. As steam came to be adopted in different places, difficulties arose which, unfortunately, were due to the wording of the Board of Trade Regulations, and at one time they threatened to hinder seriously its introduction. In some towns where steam had been introduced, the adversaries of tramways sought occasion to sue them for neglecting these regulations, and to convict them in a court of law. In several instances this was done, and in every case the plea was that the engines emitted steam from the chimney, which was illegal according to Regulation 3.

In the summer of 1883, Mr. E. H. Carter, of the firm of Carter and Carter, Chartered Accountants, of Birmingham, who was interested generally in the success of tramway enterprises, induced the various companies in the United Kingdom who had adopted steam on their lines, to combine to form a deputation to wait on the President of the Board of Trade. The deputation was received by Major-General C. S. Hutchinson, R.E., and the objections to the regulations which in practice were found to exist were carefully discussed. The result was that the Board of Trade sanctioned modifications in Requirement (*e*) and Regulation 3, and the rules as altered now stand as follow :—

THE TRAMWAYS COMPANY, LIMITED.

Regulations and By-Laws made by the Board of Trade.

The Board of Trade under and by virtue of the powers conferred upon them in this behalf, do hereby order that the following regulations for securing to the public reasonable protection against danger in the exercise by the Tramways Company, Limited (hereinafter called "the company"), of the powers conferred by Parliament upon the company with respect to the use of steam power on all or any of the tramways of the company on which the use of such power has been authorized (hereinafter called "the tramways") be substituted for all other regulations in this behalf contained in any Tramway Act or Tramway Order confirmed by Act of Parliament, or in any Order of the Board of Trade heretofore made thereunder;—

And the Board of Trade do also rescind and annul all by-laws heretofore made by them with regard to all or any of the tramways aforesaid, and do hereby make the following by-laws with regard to all or any of such tramways:—

Regulations.

I. The engine or engines to be used on the tramways shall comply with the following requirements, that is to say:—

(*a*) Each coupled wheel shall be fitted with a brake-block, which can be applied by a screw or treadle, or by other means, and also by steam.

(*b*) A governor (which cannot be tampered with by the driver) shall be attached to each engine, and shall be so arranged that at any time when the engine exceeds a speed of 10 miles an hour, it shall cause the steam to be shut off and the brake applied.

(*c*) Each engine shall be numbered, and the number shall be shown in a conspicuous part thereof.

(*d*) Each engine shall be fitted with an indicator, by means of which the speed is shown, with a suitable fender to push aside obstructions; and with a special bell to be sounded as a warning when necessary.

(*e*) Arrangement shall be made enabling the driver to command the fullest possible view of the road before him.

(*f*) Each engine shall be free from noise produced by blast, and from the clatter of machinery, such as to constitute any reasonable ground of complaint either to the passengers or to the public; the machinery shall be concealed from view at all points above 4 inches from the level of the rails, and all fire used on such engine shall be concealed from view.

II. Every carriage used on the tramways shall be so constructed as to provide for the safety of passengers, and for their safe entrance to, exit from, and accommodation in, such carriages, and for their protection from the machinery of any engine used for drawing or propelling such carriages.

III. Every carriage used on gradients steeper than 1 in 20 shall be fitted with efficient slipper brakes.

IV. The Board of Trade and their officers may, from time to time, and shall, on the application of the local authority of any of the districts through which the said tramways pass, inspect such engines or carriages used on the tramways, and the machinery therein, and may, whenever they think fit, prohibit the use on the tramways of any of them which, in their opinion, are not safe for use.

V. The speed at which such engines and carriages shall be driven or propelled along the tramways shall not exceed the rate of 8 miles an hour; and the speed at which such engines and carriages shall pass through facing-points, whether fixed or movable, shall not exceed the rate of 4 miles an hour.

VI. The engines and carriages shall be connected by double couplings.

VII. The speed of such engines and carriages shall not exceed the rate of 4 miles an hour at the following places:—

(1) Along the temporary line at the end of Tramway No. 2, authorized by the Tramways Order, 1882.

(2) The junctions of A Road, B Road, C Road, and D Lane.

(3) Between the junction of E Road with F Road and G Street.

Penalty.

Note.—The company, or any person using steam power on the tramways contrary to any of the above regulations, is, for every such offence, subject to a penalty not exceeding £10; and also, in the case of a continuing offence, to a further penalty not exceeding £5 for every day after the first during which such offence continues.

By-Laws.

I. The official bell shall be sounded by the driver of the engine from time to time when it is necessary as a warning.

II. No smoke or steam shall be emitted from the engines so as to constitute any reasonable ground of complaint to passengers or to the public.

III. Whenever it is necessary to avoid impending danger, the engine shall be brought to a standstill.

IV. The entrance to and exit from the carriages shall be by the hindermost or conductor's platform.

V. The engines and carriages shall be brought to a standstill at the following points:

(1) In F Road immediately before reaching the junction of E Road previously to commencing the descent of the gradient of 1 in 11.

(2) Immediately before passing through the facing points leading to the junction with Tramway No. 8, authorized by the Tramways Order, 1882, at the junction of H Road with K Lane.

(3) Immediately before passing round the sharp curve at the junction of H Road and L Road.

VI. The Company shall place and keep placed in a conspicuous position inside of each carriage in use on the tramways a printed copy of these regulations and by-laws.

Penalty.

Note.—Any person offending against or committing a breach of any of these by-laws, is liable to a penalty not exceeding forty shillings.

The provisions of the Tramways Act, 1870, with respect to the recovery of penalties is applicable to the penalties for the breach of these regulations or by-laws.

Signed by order of the Board of Trade this nineteenth day of September, 1884.

(Signed) Henry G. Calcraft.
An Assistant Secretary to the Board of Trade.

These alterations have been most beneficial, and as the regulations now exist, it is difficult for disaffected persons to prosecute a tramway company on some frivolous complaint, and before a conviction can be obtained a clear cause of annoyance to the public must be proved. As the result of the above revision, the number of complaints against tramway companies have considerably diminished, and the safety of the public has been in no way impaired.

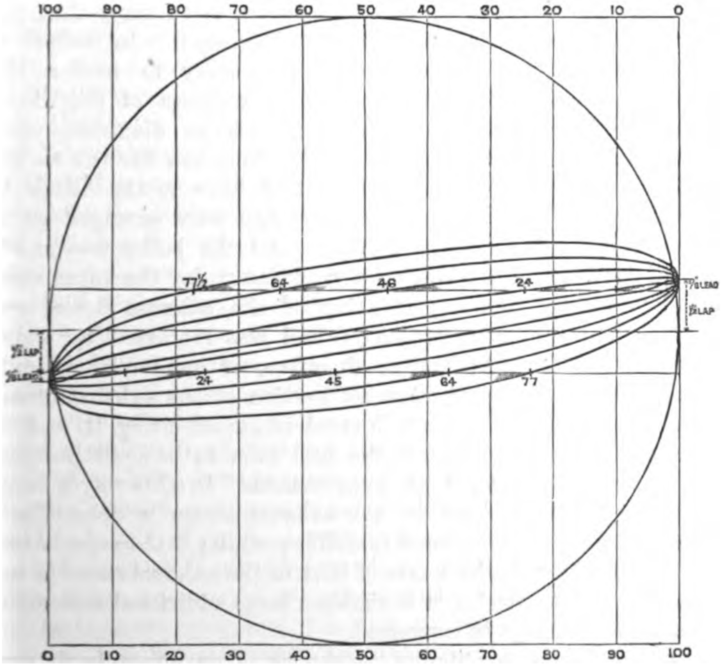
It is scarcely necessary to enumerate the various forms of tramway-engines which have been invented, all of which possess peculiarities intended to fit them for the difficult conditions under which they have to work. The Author will pass on to consider: first, what are the essential points in the construction of an engine to ensure its complying satisfactorily with the Board of Trade

Rules, and to work the traffic without being liable to failure; secondly, what are the total working expenses incurred on an average line where steam is used; and lastly, what receipts are necessary to yield a reasonable return to the shareholders.

As the Author has carefully observed for some years the working of lines with engines constructed by Messrs. Kitson and Co., of Leeds, he considers that calculations based upon these observations will probably be the most reliable he could give. Plate 4, Fig. 1, represents a sectional elevation of a tramway-engine of No. 2 class, many of which have plied for the past two years on the Birmingham and Aston Tramways, and which, after twelve months' trial, have been approved by the local authorities for use on the Birmingham Central Tramways, now being completed throughout that town. The outward appearance of this engine is no doubt familiar to many persons, as about one hundred and fifty of practically the same type have been constructed and worked satisfactorily for five years in this country and abroad. In designing a tramway-engine, as is the case with a locomotive, simplicity throughout the working parts is of the greatest importance, and it will be observed that this idea is kept in view all through the construction of this engine. The cylinders are placed as high as possible, so as to be raised out of the mud, and they are at the same time readily accessible from the front, to permit of the cylinder-cover and pistons being easily removed. The connecting-rods work directly on to the cranks on the trailing-axle, and the four wheels are coupled with side-rods as in ordinary locomotive practice. With a view to keep the valve-motion as free from dirt as possible, "Kitson's Valve-gear" has latterly always been used; its construction is shown in Plate 4, Fig. 1. This Valve-gear is a modification of the well-known Walschaert Valve-gear, largely used for locomotives on the Continent, and is well adapted for being boxed in, and for protection from dust or dirt. The lever A is attached by means of a link B to the crosshead C, to the valve-spindle crosshead by the pin D, and to the block of the radius-link F by the link E. The radius-link is pivoted at G, and the end of the lever H, forming part of the radius-link, is connected to the coupling-rod by means of the vertical-link K. The action of this valve-motion is as follows:—The lever A imparts to the slide-valve on the cylinder a motion inverse to that of the piston, and it only remains to add to that motion the port opening either forwards or backwards, which is done by the link K from the vertical motion of the coupling-rod. The distribution of steam with this gear is shown by Fig. 1, and is superior to that given by eccentrics and ordinary link-motion, and, what is of considerable importance, it possesses fewer working parts. This motion has lately been applied to several locomotives, and it is found to work satisfactorily.

It will be observed from Plate 4, Fig. 2, that this form of valve-motion, combined with outside cylinders and cranks, can be entirely encased, and thoroughly protected from mud. It will further be seen that, by merely raising a door at the side, the working parts are all visible for inspection and lubrication.

FIG. 1.



KITSON'S VALVE MOTION STEAM DIAGRAM.

The boilers of these engines are of the locomotive type, which is generally admitted to be superior both in durability and in efficiency to any other form, and it is also now universally used by agricultural-engine manufacturers. The steam when it is exhausted is admitted into the condenser on the top of the engine; this is composed of tubes, around which the atmosphere has free access to absorb the heat and condense the steam contained in them. About two-thirds of the steam which escapes from the engine is condensed in this way, and the remaining one-third is allowed to pass into the chimney to improve the draught.

The Author has made many experiments with a view to render the exhaust steam escaping from the chimney invisible, and has tried various methods of superheating, as he has long been of opinion that this is the simplest means of producing the required effect. All attempts, however, in this direction have been abandoned, as he finds the consumption of fuel, necessary to render the steam invisible in cold weather, is so great that the working expenses are considerably increased. In order to determine what amount of heat is necessary to render the exhaust steam invisible under various conditions of the atmosphere, two rows of iron tubes, 2$\frac{5}{8}$ inches in diameter, were inserted in a standard locomotive boiler from the fire-box to the smoke-box, to convey a large amount of heat to the latter to mix with the exhaust steam. These tubes were arranged so as to be opened and closed at pleasure, and the boiler was made more or less wasteful. During a cold damp day the tubes were opened wide, and the superheating of the exhaust steam was effective; but the consumption of fuel was increased by about 50 per cent. The Author is, therefore, of opinion that it is preferable to condense the largest portion of the exhaust steam in an atmospheric condenser, instead of superheating it, and to return the condensed water to the feed tank to be again pumped back to the boiler at a high temperature. In this way a large portion of the waste heat in the exhaust steam is economized, and at the same time rendered invisible; whilst if the superheater principle be adopted, the waste of heat in the exhaust steam is not prevented, and to render it invisible a large additional amount of fuel must necessarily be consumed.

Another advantage obtained by the use of an atmospheric condenser is the economy in the consumption of water, which in many places is a most important item of expenditure. In a number of tramway engines constructed for tropical climates, it has been found that, as a rule, atmospheric condensers are not required, as the capacity of the air to absorb the exhaust steam is so great that it is only on rare occasions that steam is seen to escape. Efforts have been made to economize the consumption of steam in tramway-engines by compounding the cylinders, and in this way not only to reduce the consumption of fuel, but also to avoid to some extent the difficulty of rendering the exhaust steam invisible.

The results of experiments so far have not been very successful, and the Author is of opinion that little economy can be effected with an arrangement of this kind. There is also considerable difficulty in starting a compound tramway-engine quickly. To obviate this several ingenious contrivances have been invented; but on the whole a simple high-pressure engine, like the one already described, meets the requirements most satisfactorily.

In order to comply with the Board of Trade Regulations, the engine is fitted with an automatic brake, so arranged that whenever the speed of the engine reaches 10 miles per hour, or any other required speed, it shuts off the steam and applies both the brake on the engine and also that on the car. This brake is of sufficient power to prevent the engine exceeding a speed of 10 miles an hour in descending an incline. A speed-indicator is attached, and both steam- and hand-brakes are also fitted, which are under the control of the driver. The automatic brake gear L, shown in Plate 4, Fig. 3, is entirely out of the control of the driver and cannot be tampered with; it is rigidly fixed to the trailing-axle and revolves with it; this ensures its action as soon as the engine exceeds the required speed, and it is not open to the objection possessed by governors driven by belts or chains that they are liable to be out of order when most required. It has been proposed to work the automatic brake by means of a wheel independent of the wheels of the engine, and pressed upon one of the rails. The object of this wheel is to avoid the possibility of the brake being put on accidentally when the engine occasionally slips in greasy weather. This action of the brake the Author does not consider a disadvantage, as it has the effect of showing the driver that the brake is in order. It is also evident that the danger of the independent wheel, and of the machinery connected with it, being allowed to get out of gear is considerable, as its mechanism is unconnected with the indispensable working parts of the engine. It is essential to the public safety, that tramway-engines should be fitted with powerful and efficient brakes, that the sand-boxes both on the leading and trailing ends should be large, and that the pipes coming down from them should not be liable to become choked. If these requirements are not attended to the danger of accidents in crowded streets is serious.

Attention has of late been directed to the construction of tramways, or, as they are more properly called, light railways, along the public roads in this country, and more especially in Ireland. Several engines have been constructed for Ireland of the same type as that which has been described, but of a larger size.

They are fitted in accordance with the Board of Trade Requirements, and are used, on a line which has been constructed along the side of a country road, for taking both mixed goods and passenger traffic. It is satisfactory to note that since they were put into constant service no complaints have been made by the public. Probably where wide roads are available, lines of this kind will be extended rapidly, as the cost of construction and maintenance is much less than that of an ordinary railway.

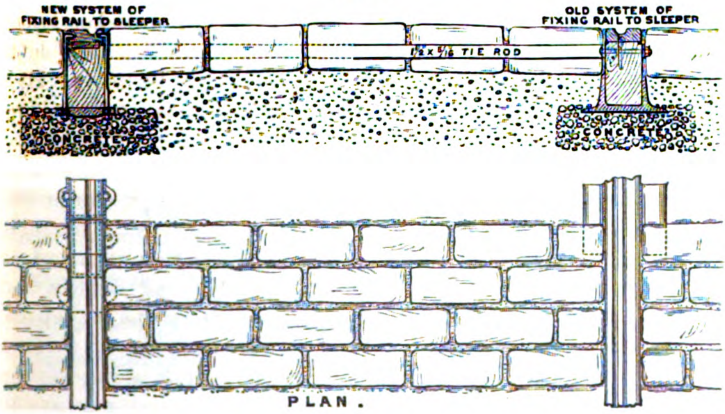
The Author has paid a good deal of attention to the combined form of tramway-engine and passenger-car, and several have been constructed which are running on light railways abroad. The most successful form of this class of engine is that introduced by Mr. W. R. Rowan. The passenger-car is supported upon two four-wheeled bogies similar in principle to the railway-carriages now generally used. The engine acts as the leading bogie, which supports one half of the carriage when empty; and when loaded a large portion of the weight of the passengers is available to increase the adhesion of the engine-wheels on the rails. It is obvious, therefore, that this form of engine and passenger-car is remarkably well adapted for light railways where fuel is expensive, or for rapid and cheap communication in the neighbourhood of towns. Engines of this description are now used on one or two lines in this country, and the working expenses are considerably less than that of an ordinary locomotive with railway-carriages.

One of the objections to the combined engines and cars is, that as soon as the engine has to be brought into the shops for repairs, the passenger-car is rendered useless, and as a matter of course a large amount of capital is lying idle. This objection is ingeniously avoided in Mr. Rowan's system; the engine and car are so arranged that the engine can be detached from the car in five minutes, and a fresh engine substituted in about the same time. The change is effected by supporting the car upon two feet, fitted with screws to relieve the weight on the engine, which when uncoupled from the car can be run out at the front through doors arranged for that purpose.

Having explained the principle of the two types of tramway-engine now in use, namely, the "Independent engine" and the "Combined engine and Passenger car," the Author proposes to consider the practical working of tramways by steam. It has been urged by the opponents of steam that the failures from its use have been more numerous than the successes; still it can be clearly shown that if a tramway is properly constructed, equipped and worked by steam, it can be made a financial success.

When tramways were first started in this country, in the year 1870, the prices of materials had risen to a very high figure, and large quantities of rails, which were then of iron, were bought at £13 10*s.* per ton. It was necessary, in view of these high prices, to reduce the weight of the rails as much as possible. The sleepers also, which were generally of wood, were exceedingly light to save expense. But the worst defect of all was the impossibility of fishing the joints of the rails of the section, Fig. 2, at first used. It was upon lines of the nature above described, which, it must be admitted, were only intended for cars pulled by horses, that the Author's experience with steam commenced. At that time it was necessary to construct the lightest possible engine which would draw a load of forty passengers. Experiments were made with various types of engines; some with vertical boilers, others with vertical engines. Different forms of condensers were also tried, and elaborate experiments undertaken to test their efficiency. As the result of the above-mentioned trials and experiments, the type of engine shown in Plate 4 was arrived at, and the Author considers that, as regards simplicity and economical effect, it cannot be materially improved. The first engine on this principle was constructed to work on the Leeds Tramways, and weighed only 6½ tons, as all the parts were made as light as possible to avoid injuring the road. This engine worked most successfully, and during the first twelve months it ran a distance of over 15,000 miles, scarcely missing a single trip, and since that time has given the greatest satisfaction.

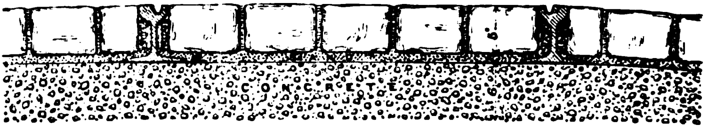
Fig. 2.


NEW SYSTEM OF FIXING RAIL TO SLEEPER
OLD SYSTEM OF FIXING RAIL TO SLEEPER
1/2 x 5/16 TIE ROD
CONCRETE
CONCRETE
PLAN.

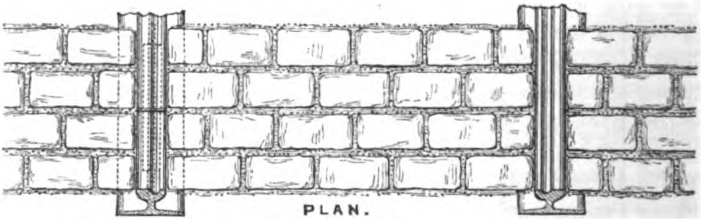
The permanent-way of tramways has, however, been much improved within the last few years, and although every conceivable section of rail has been proposed, still the ordinary flat-footed rail, used extensively on railways, has now been adopted, with this alteration, that a groove is rolled in the head (Fig. 3), and it is deeper in section. This section of rail can be perfectly fished, and the joints made as strong as the rail itself. Fig. 3 also shows a section of tramway laid in this manner, the mode of construction of which will subsequently be described. The Author has had engines running on a tramway of a section somewhat similar to the above for about two years, and the lines are in as good condition now as when the engines commenced to run.

Another great difficulty which had to be overcome on tramways laid for horse-traction was the way in which the points and crossings were arranged. It is well known that when a tramcar driver comes to a passing place, and wishes to take the left side of the road, he immediately turns his horses and directs the car on to the proper line. The engine-driver, on the other hand, has no power to turn the engine, and on lines as formerly laid, the engine frequently took the points in one direction and the car in the other, which often severed the connection between the two, and was likely to lead to serious accidents. "Drop-points" were then adopted in many places to remedy this defect. The peculiarity of these consisted in their having the groove leading into the points deeper than that leading out of them, so as to turn the engine and the car attached on to the proper road. These points, however, possessed the defect that the engine and car, when coming out of

Fig. 3.



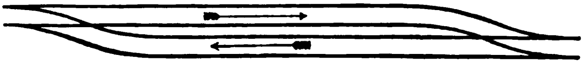
SECTION.



PLAN.

the points on to the main road, encountered a severe drop each time, which was very damaging to the springs and the working-parts of the engine. On tramways constructed recently, this defect has been remedied by a simple modification in the method of laying the points and crossings at the passing-places. The remedy has been effected by laying the rails at these places as is shown in Fig. 4, so that the engine glides straight into the points when coming in either direction. If the points are laid in this way, it will be understood that at whatever speed the engine is driven, its natural tendency will be to take the proper road. Where this principle has been followed, all necessity for moving or drop-points at the crossing places is avoided, and all danger of accident from the cause above-mentioned is removed.

FIG. 4.



Scale $\frac{1}{10}$ inch = 1 foot.

RAILS AT PASSING PLACES.

The Author, having now discussed the important points relating both to the construction of tramway-engines and also the conditions necessary for the proper laying of a tramway for steam, will proceed to consider the various expenses incidental to working the traffic on a tramway with this form of mechanical power. The figures hereinafter given are derived from several tramways, and the Author believes that they represent a fair sample of the working expenses of well-managed lines.

In order to work a tramway economically by steam, it is essential that the number of engines possessed by the company shall be sufficiently large, to render it unnecessary to employ them so continuously as to lead to the neglect of ordinary repairs. This necessity is always considered to be most important in the administration of railways, and, as the result of long experience, one of the following rules is adopted for every line:—

"Fifty per cent. of the engines on a main line should be running in service, twenty-five per cent. should be laid up for washing out, and the remaining twenty-five per cent. should be in the repairing shops."

Another rule is as follows:—

"Sixty-six and a half per cent. should be running in service, and thirty-three and a half per cent. should be either in the running-sheds for cleaning or in the repairing-shops."

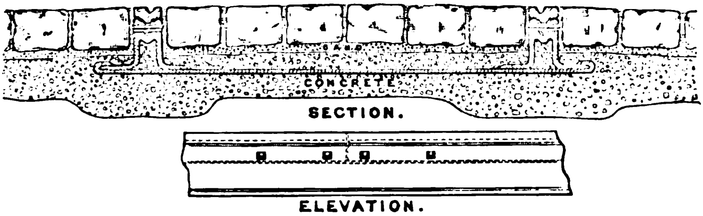
It must be borne in mind that the conditions to which tramway-engines are subjected are very different from those of locomotives. Unlike the railway-engine, which, having taken its stated runs, is then put into the shed, cleaned, and properly attended to, the tramway-engine in many cases works from morning to night, and when taken in at a late hour is cleaned and repaired by a labourer or a night fitter when the foreman has gone home. The repairs done at this time are generally unsatisfactory, and far more costly than those carried out in the daytime, when the superintendent is on the spot. This difficulty can easily be remedied by companies having an adequate stock of engines, and although they can be worked more continuously whilst new, still, when a line has been in operation for a few years, the second rule above-mentioned should be followed, and one-third of the number of engines necessary to work the traffic should be kept in reserve for repairs and in case of accident. This reserve of engines can often be utilized advantageously on holidays or days of public amusement, as the repairs can generally be arranged to suit such occasions.

The Author has carefully considered the question of repairs ot tramway-engines, as these form the most important item in the working expenses. In the case of portable engines and agricultural implements, the working parts are made by the dozen in duplicate, so as to replace parts when worn out or broken. In this way the machines are repaired far more cheaply and satisfactorily than if the repairs are done in a local mechanic's shop. This system has been acted upon for many years in several trades, and there appears no reason why a similar one should not be adopted for tramway-engines.

In railway repairing-shops an expensive staff is maintained so as to be certain that the repairs to the engines shall be properly attended to. Costly plant is also provided with which the repairs are carried out. With ordinary tramway-companies an expenditure in the sheds to fit them up in a similar manner to those of a railway cannot be afforded. In most localities it is possible to contract with local firms for turning up the wheels when the tires become worn, but beyond this all the ordinary repairs to the working parts can be made with duplicates. If this system be followed, the repairing-shops of a tramway need not be fitted with any expensive tools, and the capital of the company can be economized proportionately.

The cost of the construction and maintenance of a substantially laid and equipped line will now be considered. As an example, the Author will take a double line 8 miles in length, which is equivalent in point of cost to a single line of 16 miles. Fig. 5, shows a cross-section of a line constructed on a principle generally adopted for modern tramways. The rails, which are of steel, are laid on a bed of concrete 6 inches deep, extending under the whole of the paving, which consists of 5-inch granite setts, and the rails are maintained accurately to gauge by tie-bars placed at intervals of 3 yards. The cost per mile of a line constructed in this way is shown on the opposite page.

Fig. 5.



Dudley and Stourbridge Tramways.

The cost of the land and buildings necessary for the engine and car-sheds will amount to about £6,000. Tramway-engines capable of working ordinary passenger traffic cost on an average £780 each. Double-bogie cars capable of carrying sixty passengers can be procured at £250 each. The cost of tools and fittings necessary for the ordinary current repairs to the engines and cars ought not to exceed £2,000.

On tramways constructed in large towns, the cars can generally be run at ten-minute intervals, and the following estimate for the construction and equipment of the double line of 8 miles may be computed from the above schedule, as follows:—

	£.
Cost of a single line of 16 miles at £4,500 per mile	72,000
Land	2,000
Buildings	4,000
Tramway-engines, 19 working and 6 in reserve, total 25 at £780	19,500
Tramway-cars, 25 at £250	6,250
Tools in Repairing Shed	2,000
	105,750

Total cost per mile of single line, £6,609.

There are various ways of estimating the working expenses of a tramway. The Author considers the most satisfactory one to be

COST OF 1 MILE OF SINGLE LINE OF TRAMWAY INCLUDING ALL LABOUR AND MATERIALS.

Cubic Yards.	—	£.	s.	d.	£.	s.	d.
1,662	Breaking up and excavating roadway to a depth of 12 inches, including screening macadam for concrete where necessary	0	2	6	207	15	0
831	Portland cement concrete in a bed 6 inches thick under rails and paving .	0	10	0	415	10	0
950	Remove surplus excavated material . .	0	2	0	95	0	0
Tons.							
145	Rolled Bessemer steel girder-rails 6 inches deep, weighing 92 lbs. per lineal yard	9	0	0	1,305	0	0
Yards.							
362	Bending, fixing, and laying rails to curves 120 to 150 feet radius, single line of two rails	0	2	6	45	5	0
1,398	Ditto, ditto, straight line	0	2	0	139	16	0
Tons. cwts. lbs.							
3 8 97	No. 391 pairs of rolled steel fish-plates .	8	17	0	30	3	6
0 12 89	„ 1,564 fish-bolts ¾ inch in diameter, 3¼ inches long	13	0	0	8	6	4
2 9 79	„ 586 tie-bars with screwed ends including nuts	12	0	0	29	6	6
4 5 16	„ 16 crucible cast-steel points . .	26	0	0	143	18	9
0 17 48	„ 8 „ „ crossings . .						
0 5 24	„ 16 steel paving wedges (large) . .						
0 2 104	„ 16 „ „ (small) .						
Square Yards.							
3,320	5-inch granite paving, including shingling with fine clean gravel, and grouting with tar and creosote oil, including bedding in sand	0	10	0	1,660	0	0
3,520	Restoring macadam at edges of paving .	0	0	2	29	6	8
					4,110	3	7
	Plus 10 per cent., engineering, clerks of works, contingencies, &c.	..			411	0	4
	Total	..			4,521	3	11

Equal to £2 11*s.* 4*d.* per lineal yard for a 3 feet 6 inches gauge tramway, the portion of the roadway paved being 8 feet 2 inches in width, including the rails in the measurement.

that drawn up by Messrs. Carter and Carter, of Birmingham, and which may be clearly understood by reference to the accompanying Tables Nos. 1 and 2, which are applicable for the registration of both the monthly and the annual working expenses of any steam-tramway.

The principle adopted throughout is to estimate each item of expenditure and receipt separately as a mileage rate, and consequently the importance of each expense can be considered with a view to its reduction, and further each asset can also be discussed with the object of its improvement.

The most difficult items of expenditure to compute, in the working of a tramway, are those connected with the depreciation of the line and rolling-stock. It is generally found that if a tramway-line has been substantially laid, for the first three or four years very little expenditure is necessary beyond the ordinary current

TABLE No. 1.

STEAM TRAMWAYS COMPANY.

Expenditure for months. Ending 188 .

Description.	Cost.						Cost per Mile.	
	£.	s.	d.	£.	s.	d.	d.	d.
To Engines.								
Wages							1·41	
Fuel							0·90	
Water							0·09	
Stores							0·08	
Repairs							0·80	3·28
To Cars.								
Wages							0·13	
Stores							0·02	
Repairs							0·26	0·41
To Traffic.								
Wages							1·03	
Repairs							0·29	1·32
To Permanent Way.								
Repairs							0·15	0·15
To General.								
Stationary . . .							0·23	
Incidentals. . .							0·08	
Coal and gas carriage							0·07	
Compensation . .							0·14	
Insurance . . .							0·03	
Rents and rates .							0·68	
Repairs							0·09	
Directors' fees . .							0·43	
Professional charges							0·14	1·89
Total . . .								7·05
Depreciation .								2·28
Total expenses								9·33

TABLE No. 2.

STEAM TRAMWAYS COMPANY.

Receipts for months. Ending 188 .

Description.	Amount.						Amount per mile.	
	£.	s.	d.	£.	s.	d.	d.	d.
By traffic . . .								
By sundries . . .								
Total								

Passengers carried..

Mileage run..

repairs, such as the resetting of the paving, &c., which ought to be defrayed out of revenue.

Evidently, therefore, if it is agreed when a tramway has been constructed, that a certain percentage on the first cost of the line shall be written off each year, it will practically form a sinking-fund. Suppose this fund to be allowed to accumulate at the rate of 3 per cent. per annum upon the original capital expenditure, and interest on this reserve be taken at 5 per cent. and allowed to accumulate also, the cost of the line will be paid off in about twenty years. Judging from experience, this provision appears to be ample, provided the line has been substantially constructed at first.

The next item of depreciation is the rolling-stock, which is the largest and by far the most important item of expense in the working of a tramway. It is well known that the life of a locomotive may be extended considerably over twenty years; but it must be remembered that during that time several of the more costly parts are renewed and extensively repaired; consequently, in the endeavour to compute its life, with a view to decide what amount ought to be laid aside for a depreciation fund, it cannot be considered to last so long. In the case of tramway-engines the necessary renewals are more frequent, owing principally to the smallness and the number of the parts, the indifferent treatment which as a rule they receive, and the frequent collisions they undergo in the streets, all of which tend to shorten their existence. The Author is, however, of opinion that, where the ordinary repairs are paid for out of revenue, a reserve of 10 per cent. for depreciation of engines similar to that above described is amply sufficient to form a renewal fund. The cars also are subject to a somewhat similar rate of depreciation, and a reserve fund of 10 per cent. on them ought to be charged.

The two remaining items, the depreciation of which should be allowed for annually, are the buildings and tools, and these may be taken at 2½ and 5 per cent. respectively.

A car can usually be run on tramways from 70 to 75 miles per day, and as in many places the Sunday traffic is as heavy, or heavier, than that on week days, it will be assumed that the cars in service run 75 miles per day throughout the year. At this rate, therefore, if a ten-minutes service is maintained, the total mileage run per annum on the line above mentioned will be 19 × 75 × 365 = 520,125.

The depreciations as above stated, when computed as a mileage rate on 520,125 miles run per annum, will severally stand as follows:—

	£.		Per cent.	d.
Line	72,000	at	3	0·99
Buildings	4,000	,,	2½	0·05
Engines	19,500	,,	10	0·90
Cars	6,250	,,	10	0·29
Tools	2,000	,,	5	0·05
				2·28

The remaining items of expenditure connected with the working of a tramway are the running-expenses. These items, also computed as a mileage rate, and inserted in Table No. 1, have been taken from the annual returns of a successful tramway, and one where the engines are maintained in thorough order. On this line during the twelve months a mileage of 176,528 was run, and the number of passengers carried was 1,518,747; the results of working, therefore, from so large a mileage are probably as nearly accurate as possible. It will be observed that these expenses amount to 7·05*d.* per mile run, which, together with those for depreciation previously computed, reach 9·33*d.* The above sum has been arrived at after considerable experience, and the Author considers that, on a tramway with average gradients, 9¼*d.*

per mile should defray all the necessary expenses. Having ascertained the absolute working cost per mile of an average tramway, it can easily be calculated what dividend can be paid to the shareholders if the receipts per mile are also known. These last vary considerably on different tramways; they are lower as a rule on lines worked by horses than on those where steam is used, for reasons which will presently be explained.

Assuming, however, that the total expenses amount to 9¼*d.*, and the receipts to 12¼*d.* per mile, which are ordinary values for horse-tramways, the difference of 3*d.* per mile may be considered as profit, which, if multiplied by the total number of miles run throughout the year, yields £6,501 11*s.* This would pay a dividend of 6·14 per cent. on the share capital of £105,750, or 2·04 per cent. for every penny by which the receipts exceed the expenses.

In many places where tramways are worked by steam the receipts far exceed those above mentioned. Thus on the Birmingham and Aston Tramways, the average receipts per mile amount to 17*d.*, and on the Vale of Clyde they reach 21*d.* In these instances handsome profits are realized, which would not be the case unless steam-traction was employed.

Having now considered the cost of working a steam-tramway, item by item, and having also obtained some idea of what the receipts may be, but which vary in different localities, it remains to discuss what course should be adopted by tramway companies to improve their profits and increase their dividends.

It will be observed by reference to Table No. 1 that the cost of fuel amounts to 0·90*d.* per mile, and this item varies very little whether a small or a large load of passengers is carried. The superiority of steam over horses therefore consists in the fact that a heavy load of passengers can be carried by the former practically as cheaply as a light one, whilst with the latter the cost increases rapidly with the number taken. It is therefore to the interest of tramway companies, especially in populous districts, to use large cars made to accommodate sixty passengers or more, and, as has been shown above, this can only be done where mechanical power is employed. The cars must also be filled, if possible, to overflowing, and in order to effect this the fares must be moderate, consequently the public will be pleased, and tramways made popular and prosperous. On tramways, also, where steep and long gradients are encountered, steam can be used at a profit where horses are utterly unsuitable, owing to the wear and tear which is found to take place. The Author has ascertained the cost of horse-traction on steep and long gradients, and he has found that it varies from

8½*d*. to 9¾*d*., which includes only the driver and the horses. The comparative cost of steam under similar conditions will amount to from 4*d*. to 4½*d*.

In conclusion, the Author desires to explain that in preparing this Paper his object has been to lay down what he believes to be the true principles on which a steam-tramway should be worked so as to prove a financial success, rather than to discuss the relative merits of the various systems of mechanical power which are in use for this purpose. He has, however, carefully considered the merits of the various forms of mechanical power proposed from time to time, and is strongly of opinion that, up to the present, no form of motor is able to compete favourably with steam in point of economy and efficiency. He wishes to tender his best thanks to Mr. E. H. Carter, of Birmingham, for supplying various statistics, without which he could not have gone so fully into the question of cost; and to Mr. E. Pritchard, M. Inst. C.E., for valuable information connected with the construction of tramways.

This Paper is accompanied by several diagrams, from which Plate 4 and the Figures in the text have been compiled.

(*Paper No. 2004.*)

"The Sydney Steam-Tramways."

By Walter Shellshear, Assoc. M. Inst. C.E.

Tramways have now become recognized, especially in newly-developed countries, as the most convenient mode of connecting a large city with its suburbs; and the system of steam-tramways in operation in the city of Sydney is perhaps the most advanced in the world. As the question of a more general adoption of mechanical power on tramway lines in Great Britain is engaging attention at the present time, it may not be uninteresting to the Members of the Institution to be furnished with a few particulars regarding the success that attends steam-traction in Sydney.

When it was decided to hold an International Exhibition in Sydney in 1879, a Bill was hurriedly passed through Parliament empowering the Government to construct a tramway from the railway terminus at Redfern to within a few yards of the Exhibition gates in Hunter Street. It was resolved to adopt steam as the motive power; accordingly four 12-ton tramway-motors were ordered from the Baldwin Locomotive Works of Philadelphia, U.S., and eight bogie double-decked cars, seated for ninety passengers, sixty inside and thirty out, from Messrs. Brill and Co. of the same city. The permanent way was constructed on the longitudinal principle, with a 62-lb. grooved iron rail, designed to the Larsen pattern. The cost of this line, 1 mile 45 chains in length, including rolling-stock, was £22,269.

That an improved method of transit was much needed is shown by the fact that for the one hundred and six days of 1879 from the opening to the 31st of December, 443,341 passengers were conveyed. The line was barely open when the public, appreciating the convenience of the system, set up a general agitation for steam-tramways in every possible direction. The line became so exceedingly popular, that in a few months a Bill authorizing the construction of no less than fifteen lines, with power to construct more along any other route or routes, was passed by the Local Legislature.

At the end of 1880 a length of 4 miles of tramway was open for traffic, the capital expended upon which, inclusive of rolling-stock and workshops, was £60,218. The number of passengers carried during the year 1880 was 2,086,897, equal to 521,724 per mile of line. As, however, of the 4 miles of line in operation 2½ miles were opened during the last four months of the year only, the average annual mileage did not exceed 2½ miles. The number of passengers who travelled over this length was equal to 834,758 per mile of line.

During 1881 an additional length of 5½ miles was opened, making the total 9½ miles; the capital expended upon which, inclusive of rolling-stock and workshops, was £169,450. The number of passengers carried during the year 1881 was 7,090,125.

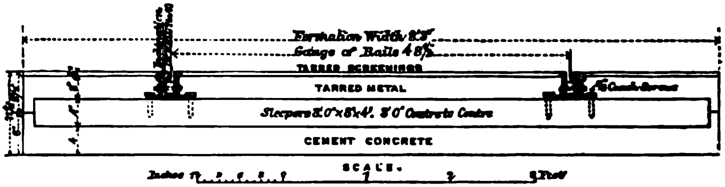
At the end of 1882 the total length open was 22 miles (about two-thirds being double line), and the capital expended, inclusive of rolling-stock, machinery, and workshops, amounted to £412,561. The number of passengers in this year reached 15,269,100, equal to 986,400 per average mile of line; while the earnings amounted to £8,142 per mile, results which exceed any published tramway transactions in any part of the world. It may be observed that the number of passengers represent the number of fares collected, the long lines being divided into sections about 2 miles in length, and a separate fare collected for each section.

Construction.—The lines are laid to a gauge of 4 feet 8½ inches, with a 5-feet way. The sharpest curves have a radius of 1 chain 50 links (99 feet), but, with the exception of about half-a-dozen sharp corners, there are few curves with a less radius than 3 chains.

Gradients.—The steepest gradients are about 1 in 18. On one road the gradient for a considerable length is 1 in 23; the heaviest section has a ruling gradient of 1 in 20 for about a mile, with 3-chain curves.

Permanent Way.—Much difficulty has been experienced with the permanent way; but this, like many failures on other tramways and railway lines, has arisen from the rails being of insufficient strength to support the weight of the motors, many of which are of 12 tons weight on four coupled wheels. The original line was never intended for steam-traction; the rails were of inferior quality, having been re-rolled in the Colony from old railway metals; and the road had to be entirely relaid after a short life of about eighteen months. In 1879 the tramway engineer designed a rail, similar in some respects to the "Barker" rail, to be supported on chairs and cross-sleepers. It was intended that this rail should be of steel; but it was eventually manufactured in the Colony of iron, and, to facilitate the rolling, the "Esk Bank Iron Company" obtained permission to alter the shape of the guard of the rail. This modification destroyed the value of the guard, as it afforded no assistance to the rolling-stock when rounding the curves, and great trouble was experienced from the motors and cars leaving the rails on the curves. The system was soon abandoned, and, with the exception of a short length, the line has been entirely relaid. Experience in the Colony has therefore been dearly bought. The tramways are now laid on a cross-sleeper road (Fig. 6) with ordinary 41-lbs. steel rails of the Vignoles type, with a separate guard-rail weighing 21 lbs. per lineal yard; the sleepers are rectangular, 8 inches by 4 inches by 8 feet, spaced 3 feet apart from centre to centre, laid on a 4-inch bed of Portland cement concrete, composed of 1 part of cement, 1 of sharp sand, and 6 parts of blue-stone, broken to a 2-inch gauge; the roadway is formed of tarred blue-stone. Some of the lines were laid with colonial iron rails, of the same section and weight as the above, but, being of insufficient strength, steel rails soon had to be substituted. This road promised to be satisfactory but for a weakness in the joints; the rails being fished over the sleepers, the ever-repeated depression of their ends under passing loads gradually destroyed the sleepers under the joints, constant packing became necessary, and in some cases new sleepers have had to be laid. Where the street traffic is light, the tarred blue-stone answers fairly well, and if properly rolled it forms a good solid face, but with heavy street traffic much trouble is experienced in keeping the surface of the road up to the rail level. On one of the lines, for about ½-mile, wood-paving from gutter to gutter has been used, but the results have not been an unqualified success; the depth over the cross-sleepers being insufficient, many of the blocks have worked loose. A portion of another line for a few chains, where the street traffic is heavy, is laid with 70-lb. steel rails of the Vignoles pattern, as used on the railways, with cross-sleepers supported on a bed of concrete. The street is paved from kerb to kerb with granite setts, the blocks next the rail being cut to clear the flanges of the wheels. This construction is very substantial, but the notched cube setts next the rail have been badly cut

FIG. 6.



up by the street traffic, and it has been found necessary to use a guard rail. For a metalled road, or where asphalte paving is employed, a cross-sleeper road, similar in some respects to the one adopted, should make a substantial and cheap tramway.

Rolling-Stock.—Besides the motors furnished by the Baldwin Locomotive Works, two engines have been supplied by Messrs. Kitson and Co., of Leeds; one engine by Messrs. Merryweather and Sons, of London, and there is one experimental steam-car.

The Baldwin Motors.—These are neatly designed saddle-tank locomotives, enclosed by cabs entirely concealing the boilers and most of the machinery. No attempt has been made at condensing, but the engines are fitted with a chamber into which the exhaust-steam passes, muffling the noise of the exhaust sufficiently to render it unobjectionable. Four different sizes of these engines are at work. The first has four wheels coupled, cylinders 11 inches in diameter, with a length of stroke of 1 foot 4 inches, wheels 2 feet 11 inches in diameter, wheel-base 6 feet. The second has six wheels, four coupled, 2 feet 11 inches in diameter, with two-wheeled trailing bogie-wheels 2 feet in diameter, cylinders 11 inches in diameter, length of stroke 1 foot 4 inches, extreme wheel-base 9 feet 3 inches. The third has four wheels coupled, cylinders 10 inches in diameter, length of stroke 1 foot 2 inches, wheels 2 feet 11 inches in diameter, wheel-base 6 feet. The fourth has four wheels coupled, cylinders 9 inches in diameter, length of stroke 1 foot, wheels 2 feet 11 inches in diameter, wheel-base 5 feet 6 inches. The cylinders of these motors are horizontal, and, the working-parts being well balanced, they run with remarkable smoothness considering their short wheel-base. The larger engines can take two double-decked cars, weighing 7 tons 4 cwt. each when empty, with a full load of passengers, nominally one hundred and eighty, but the cars are often packed with considerably more than two hundred passengers—up an incline of 1 in 20. For neatness of design, handiness in working, and careful construction, these motors have much to recommend them; but, as must always be the case on dusty and sandy roads, the wear and tear are by no means a small item of maintenance. At the end of 1882, thirty-seven Baldwin motors were in use on the tramways, and about twenty more had been placed on the roads up to October 1883.

The two Kitson motors are mounted on six coupled wheels; they were originally fitted with a system of condensing tubes, but the condensing arrangement has since been removed, as it was of little service, and the steaming-power of the boiler was much reduced. It is doubtful if any form of condensing-motor of moderate weight could be constructed to perform the work required on a line with gradients as steep, and rolling-stock as heavy, as on the Sydney lines. The Kitson engines are capable of pulling a heavy load; but the cylinders are inclined at a considerable angle, and, the gearing being somewhat heavy, they do not run so smoothly as the Baldwin motors. The engine supplied by Messrs. Merryweather and Sons was too light for the requirements of the traffic.

The Government are now having some experimental steam-cars constructed in Philadelphia, and it is hoped by their adoption greatly to reduce the proportion of dead weight to paying load. The car may be described as a combination of an ordinary tram-car with a motor. It is divided into compartments in the usual manner, with the exception of a space being reserved at one end to receive the motor. The upper deck runs the whole length of the car, and is accessible by two staircases. The motor is, to all intents and purposes, completely self-contained, as it can be moved in or out of the car at pleasure. The car has been designed to convey eighty passengers at a speed of 10 miles an hour, on a gradient of 1 in 19; the steam-pressure is 130 lbs. per square inch. The advantage of this system is, that whilst with an excessive load the ordinary motor has only its own weight to rely upon for traction power; this car, if so loaded, throws half the weight of the extra load upon the driving-wheels, thereby giving additional adhesion, by which the difficulty of starting an overloaded tram is entirely overcome.

Cars.—All the cars are built on the American bogie principle; they are mostly double-decked, with a roof over the upper-deck, the inside or lower deck being divided into compartments with ten seats in each. The large cars are seated for ninety passengers, and weigh 7 tons 4 cwt.; the small ones are seated for sixty, and weigh about 4 tons 16 cwt. With the exception of the first eight cars imported from Philadelphia, the whole of the stock has been manufactured by local firms. A special feature about these cars is the system of couplings employed, the draw-bars being connected to the cars as near the bogie-centres as possible, and free to move from side to side to any reasonable extent. The bars are very strong, and provided with sockets into which the connecting-link is fitted, with only sufficient clearance to allow of its being coupled and uncoupled with freedom; when the bars are coupled the connection becomes virtually a rigid bar, and, the attachment being near the centres of the bogies, the cars take the curves with ease. The rolling-stock is fitted throughout with the vacuum-brake as well as with powerful hand-brakes.

The stock at the end of the year 1882 consisted of eighty-one cars and five bogie-trucks.

Workshops.—The Government are erecting extensive workshops; several acres of land have been levelled, a tram-car shed 300 feet long with three lines of rails has been laid through it, and a motor running-shed of the same dimensions, together with other buildings, have been erected.

The Sydney tramways ought more correctly to be called the Sydney Street Railways, as they have more in common with railways than with what is generally understood by tramways; stoppages being only made at fixed points along the different routes. There can be no question that they are a great convenience, and, considering the narrowness of the streets and the speeds at which the trains are run (often considerably exceeding 10 miles an hour), they are by no means as dangerous to the other traffic as might be supposed, and accidents, taking into consideration the magnitude of the service, have been remarkably few. The horses in the streets have become used to them, and regard them with unconcern. Some idea of the magnitude of the service may be gained from the fact that along one street in the city no fewer than nine hundred and seventy-three trams pass daily, and on public holidays this number is considerably exceeded.

From the experience gained in Sydney, the Author concludes that, for steam-tramways, the greatest attention is necessary in the design of the permanent way, and, with loads as great as those carried on the Sydney line, a substantial rail thoroughly well supported will be found essential to economy. Also that it is most advisable to have the streets well paved, so as to reduce the amount of grit on the road as much as possible, and thus to diminish the great wear and tear of the locomotives.

The tramways are under the management of Mr. C. A. Goodchap, the Commissioner of Railways of the Colony, and the Author is largely indebted to his annual reports for much of the information contained in this Paper.

The satisfactory results achieved on the Sydney tramways seem to show that the time is fast approaching when horse-traction must yield to the superiority of mechanical power, and when horse-tramways, instead of being the rule, will be the exception. The late Secretary for Public Works of the Colony, speaking of the system, said: "Besides providing pleasant and convenient means of transit from one place to another, and economizing time in travelling, the extension of the tramway-system enables the working classes to form homes in the healthiest part of the suburbs, and affords them ample opportunities of reaching, at a moderate cost, the business and working centres of the city. The masses are enabled to leave the crowded city when their day's work is over, and thus, by domiciling the population outside the limits of the city, new localities are opened up, long-established ones are improved, and property is enhanced in value wherever the lines are extended."

The Paper is illustrated by a map of Sydney and by several photographs and drawings, from one of the latter of which the figure in the text has been engraved.

APPENDIX.

REVENUE and EXPENDITURE of all the LINES in OPERATION DURING the YEARS 1880 to 1883 INCLUSIVE.

	1880.			1881.			1882.			1883.		
Number of miles open . . .	4	Cost per Train-mile.	Per cent. to Earnings.	9½	Cost per Train-mile.	Per cent. to Earnings.	22	Cost per Train-mile.	Per cent. to Earnings.	25	Cost per Train-mile.	Per cent. to Earnings.
Train mileage	84,074			296,906			670,649			1,076,096		
	£.	d.		£.	d.		£.	d.		£.	d.	
Locomotive power	6,997	19·97	36·86	26,150	21·14	41·81	60,710	21·73	48·11	107,093	23·89	56·16
Permanent-way expenses . .	1,579	4·51	8·32	13,552	10·95	21·67	17,481	6·26	13·85	30,977	6·90	16·25
Traffic ,, . . .	3,722	10·63	19·61	11,069	8·95	17·70	22,836	8·17	18·09	37,558	8·38	19·69
General charges	1,146	3·27	6·04	1,336	1·08	2·13	2,109	0·75	1·67	3,249	0·72	1·70
	13,444	38·38	70·83	52,107	42·12	83·31	103,136	36·91	81·72	178,877	59·89	93·80
Balance	5,536			10,442			23,066			11,822		
	18,980			62,549			126,202			190,699		
				£.			£.			£.		
Capital expended on construction	. . . .			104,561			281,951			366,330		
,, ,, rolling-stock, workshops, machinery, &c. .	. . . .			64,889			127,610			177,775		
	£.											
Total capital expended . . .	60,218			169,450			412,561			544,105		
	Receipts.	Earnings per Train-mile.		Receipts.	Earnings per Train-mile.		Receipts.	Earnings per Train-mile.		Receipts.	Earnings per Train-mile.	
	£.	d.		£.	d.		£.	d.		£.	d.	
	18,980	54·18		62,549	50·56		126,202	45·16		190,699	42·53	
Net earnings per cent. on capital	12·34			6·16			6·80			2·22		

Discussion.

Hon. R. C. Parsons.

The Hon. R. C. PARSONS said that Mr. Shellshear in his Paper had drawn attention to some engines sent out by Messrs. Kitson and Co. to Sydney, and compared their working with some supplied by the Baldwin Locomotive Works, which, he said, worked more smoothly. The cylinder, he added, was so much inclined to the horizontal, as to give the engine an unpleasant movement. He thought that most locomotive manufacturers would admit that the cylinder and connecting-rod of the engine in question were not inclined excessively to the horizontal. The latter was long, more than four times the stroke of the engine. Many locomotives were now made with a stroke of three times, consequently the action produced by the angularity of the connecting-rod to the horizontal was practically of no importance. When the engines were sent to Sydney, three were also sent to Queensland to work on the tramways there; and it appeared from the reports that had been received, that they had been driven up to 20 miles an hour without any difficulty. Messrs. Kitson and Co. had also made other engines of a similar type, and he himself had driven them up to 30 miles an hour on a tramway. The parts, therefore, could not be unnecessarily heavy. It had been stated that the line was broken up several times, and he thought that some of the results produced were due to the joints in the rails being so much out of repair, causing the engines to jolt excessively. It was stated in some of the reports they had received, that the drivers riding on the engines had frequently become sea-sick from the jolting.

Sir Charles Hutton Gregory.

Sir CHARLES HUTTON GREGORY, K.C.M.G., Past-President, thought that all the members must have been greatly interested in the Papers that had been read. It was asked, "What's in a name?" Very often there was a great deal, and he thought that the misnomers applied to different systems of railway sometimes involved a misleading error. The word "tramways," for example, was applied in a sense far different from its original signification. In Tredgold's treatise on railways published in 1825, they were divided into tramway-roads and railroads, the tramway-road being a road constructed of plates for the north country trams to run upon, with flanges on the plates themselves; the railroad having what was then called the edge rail, with flanges on the wheels. The public had an idea that what were erroneously called tramways were much cheaper than the ordinary system of railway. The nearest approach to the form of a tramway was in some of the earlier rails used in street railways; but it had been found that those earlier forms were so inadequate to the work they had to do, that the details of a road, the mode of laying it, and especially the weight of the rail, had to be materially altered, so that the cost of street railways (as he thought they ought to be called), where there was a large amount of ordinary street traffic running over and across them, was very great indeed. It would be seen from the second Paper, that the cost of the lines in Sydney far exceeded, mile per mile, that of ordinary railways. He thought that railways might be divided into ordinary railroads, in which land and works of all sorts had to be provided for the traffic of the railway proper; common road railways, where there was naturally very much saving in works, and street railroads, abandoning altogether the misleading expression "tramway," which was generally supposed to imply cheapness. In the treatise on railways to which he had referred, he had found an illustration of the saying that there was nothing new under the sun; at page 179 there was a drawing of a railway wagon which Mr. Tredgold proposed should be mounted on two four-wheeled bogies. He thought few were aware of this proposal at so remote a date as 1825. Sir Charles Hutton Gregory.

Mr. E. Woods, Vice-President, said the Papers would prove of great use to the members when studying the subject of traction on tramways. Mr. Parsons had stated that the steam-tramway cars were first used on the Vale of Clyde Railway. He believed, however, that the late Mr. John Grantham, M. Inst. C.E., was the pioneer in the introduction of steam-tramway cars for traffic. He made an engine which ran for many years on the Wantage tramway, and which he believed was still running, carrying traffic from the Great Western station to the town, on a considerable gradient, over a length of a mile or a mile and a half, the line being laid along the common road. The members could compare the results of English practice, and to some extent of colonial and foreign practice, with the practice of railways in Sydney. The Sydney tramways, he observed, were laid very much like English railways, with cross sleepers, with flat-footed rails, or rails of Vignoles section, simply grooved on the top. That was a form of rail which recommended itself to many engineers in this country. He had recently received a letter from his son in Monte Video, stating that he had been studying the subject of tramways there, and had ascertained that preference was given to the Mr. Woods.

Mr. Woods. form of rail which had been recommended in both the Papers, not only for tram-cars drawn by horses, but for steam-motors. With reference to the comparison instituted between the locomotives, Mr. Shellshear had stated that the Baldwin motors, of which there were fifty-seven, were greatly preferred to the English engines. Mr. Woods, however, saw no reason why engines of English manufacture should not be as good as those of American manufacture. He had found that to be the case in his own experience. He had engines constantly in use for years, both from the United States and from many of the leading English houses, and he could certainly state that the English engines compared most favourably with the American. He could not conceive that the cause of the oscillation described as existing in the Kitson engines was that assigned to it, namely, the slight inclination of the cylinders. In the engines at Sydney, the use of condensation had been abandoned. He supposed that the inhabitants of the town, and the municipality, did not care so much as English authorities did about the noise or the nuisance occasioned by the escape of steam from the engines. No doubt the climate had an important effect in rendering condensation in that country of less importance. The degree of humidity was less; the atmosphere therefore took up the steam, and rendered it invisible, so that the nuisance was removed. Mr. Parsons had said that he did not consider it expedient to attempt to condense more than two-thirds of the steam that escaped through the chimney, the remaining one-third being applied in producing blast. Now that the Board of Trade regulation had been amended in favour of the tramway companies, he supposed from Mr. Parsons' statement, and from Mr. Woods' own observation, that the escape of that one-third was comparatively unimportant. Superheating at one time was thought to be essential, but that seemed now to have been abandoned, upon the ground not only of the unnecessary complexity of the parts, but of the largely increased consumption of fuel incidental to the superheating. The comparative statement of the working expenses by the two systems, the Sydney and the English, was of great value. It was stated in Mr. Shellshear's Paper that the Sydney system of steam-tramways was perhaps the most advanced in the world. If so it might be expected that the working expenses would be exceedingly moderate; but, on comparing them with those given in Mr. Parsons' Paper, it would be found that they were much greater. In 1880 the cost per train-mile at Sydney was 38·38*d.*, in 1881 42·12*d.*, and in 1882 36·91*d.*, the mean being about 39*d.*

Mr. Woods.

per train-mile,[1] without any allowance for depreciation and other expenses included by Mr. Parsons, who had taken the case of a railway, the name of which had not been given, where the expenses were only a little over 7*d.* per mile, or, together with what he had put down for depreciation, 9½*d.* as compared with 39*d.* at Sydney. The cost of locomotive-power alone was 21*d.* per train-mile in Sydney, while on the line mentioned by Mr. Parsons it was only 4½*d.* Making every allowance for the high wages paid in Sydney, and also for the increased cost of materials, and perhaps of coal, the difference was he thought too great to be accounted for by those considerations. There had been a falling-off in the percentage of earnings during the three years. In 1880 the percentage of earnings with reference to capital expended in lines open was 12·34, in 1881 it fell to 6·16, and in 1882 it was 6·80. He could not discover why such a great reduction should have taken place, and it might be interesting to have it explained. He also observed that there was a very considerable increase in the percentage of working expenses, which in 1880 was 70·83, and in 1881 and 1882 averaged more than 82 per cent.

Mr. Norman Scott-Russell.

Mr. NORMAN SCOTT-RUSSELL observed that Mr. Parsons' Paper was entitled "The Working of Tramways by Steam;" but it seemed to him that the impression must have been produced that steam on tramways was still in an experimental stage, and that the experiments were confined to one type of engine on the Leeds and Birmingham tramways. The fact was that steam on tramways was now regularly employed in Gateshead, Stockton, the Hartlepools, Tynemouth, Bradford, Blackburn, Burnley, Bury, Rochdale, Stoke, Dewsbury, Batley, Coventry, Brighton, and one or two other towns. In Mr. Shellshear's Paper the Sydney tramways were spoken of as perhaps the most advanced in the world, whereas there was one line in England, the South Staffordshire, 22 miles in operation with thirty-five engines, and another, the Manchester, Bury, and Rochdale, which was probably the longest in the world, with 32 miles open to traffic, 62 miles authorized, and fifty engines. Altogether there were in England 160 miles of tramway open to traffic, worked by two hundred and forty engines made on the Wilkinson, Merryweather, Kitson, and Falcon systems. In bringing those tramways to their present state great difficulties had to be contended with, and engineers had been obliged to purchase their experience. At first the rails were too light, and the engines too heavy; and both managers and drivers

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[1] When these remarks were made the details for 1883 had not arrived.—Sec. Inst. C.E.

Mr. Norman Scott-Russell. had to be trained. With regard to the permanent way, nearly all engineers appeared to have considered the girder-rail described in Mr. Parsons' Paper as the best. He thought, however, the rails might be improved by being made heavier. An addition of 10 lbs. a yard to the weight of a rail would add considerably to its endurance, and only 3 per cent. to the cost. A source of weakness in the rails was of course the butt-joint, and that was more the case in tramways than in railways. Any one who had noticed a tramway would see that the water soaked through, and every time an engine went over it pumped out the water, which afterwards filtered in again, so that the cement not only close to the butt but all round worked out. Many of the fish-joints seemed to him not nearly so strong as they might be. Another defect was to be found in the points and crossings. Mr. Parsons had illustrated a form of siding, but it was not always possible in crooked streets to arrange the crossings in the way desired. He had seen tramways in which the leads into the crossings were perfectly straight, and in which, nevertheless, cars had gone the wrong way. He believed that some mechanical points had been made, and he thought that method would have to be adopted or a self-acting spring point. The gradients in tramways were sometimes very steep; he thought that any above 1 in 16 or 1 in 17 ought to be avoided. Some were as steep as 1 in 11, but such gradients were so near the limit of adhesion as to be dangerous. The power required to draw cars up steep gradients increased rapidly with the steepness. Up to 1 in 40, and even 1 in 30, there was not very much difficulty, but beyond that gradient the necessary power increased greatly. He should like to point out the work to be done in making engines to draw cars on tramways. The usual car weighed about 4 tons, and carried sixty passengers, weighing another 4 tons; the engine to draw it weighed about 9 tons, making a total of 17 tons. The actual HP. necessary to take 17 tons up a gradient of 1 in 20 was 38; and to show that that was not very much out, he might mention that on one line an engine hauling 18½ tons, which theoretically required 42 HP., was found, by taking diagrams from it, to absorb 48 HP., or an addition of 6 HP., which was not unreasonable when allowing for the friction of the mechanism. In regard to the steam tram-engine, however, the power was enormously disproportionate in comparison with what was done every day with horses, where two horses were able to drag a car up considerable inclines. He thought he could explain some part of that peculiarity. Of course there was great absolute loss in

Mr. Norman Scott-Russell.

that half the power was required to take the engine alone, leaving 18 HP. to drag the car up the incline. A great deal of that was due to the HP. needed for the speed required with steam, which was much greater than with horses. Still there remained something to be explained, and he was sorry to have to upset one of the idols which had been set up from the time of Watt, and to say that the 33,000 foot-lbs. HP. which had been regarded with so much reverence was not HP. A tram-car horse actually took up something like 65,000 lbs., or nearly double the amount supposed. The engine constructed at the Falcon Works for tramway purposes was shown in Plate 5, Figs. 1 and 2. It was in some respects like that of Messrs. Kitson, with this material difference that the cylinders were inside instead of being outside, and there was also a locomotive boiler. All the mechanism was shut in from below, thus keeping it free from dust and dirt, and it was accessible from above. Considerable attention had been devoted to the brake and governor gear, which was a very serious point on account of the danger in going up an incline. What was called the fifth wheel had been adopted. It was not considered necessary to stop the engine to remind the engine-driver that the brake was in working order. The fifth wheel ran on the rail. It was connected directly by a shaft with a ball governor, which, when it expanded, opened a little valve, putting brakes both on the car and on the engine, and at the same time cutting off steam. Further, by a reducing valve, the driver could put on the steam- and the car-brake at the same time. It was a self-acting valve, which regulated the pressure. With regard to the working cost, it was hardly possible to compare one line with another, in consequence of the difference of the gradients. Assuming that along a level line 1 HP. was required to draw a car each way, or 2 HP. for the complete turn, on a gradient of 1 in 40, it would take 3 HP. to go up an incline, none being required to run down, so that it took 50 per cent. more power to work a gradient of 1 in 40 than it did to work a level line. It therefore took 50 per cent. more coal, and the same thing would apply to all the other expenses of working. The engine, for example, being more heavily strained, would need more repairs, and would use more oil; and the same might be said of another great source of wear and tear on tramways, viz., of the tires. The life of a tire on lines with heavy gradients was about 21,000 or 22,000 miles, which any one acquainted with railways would know to be short. The cheapest worked lines in the kingdom

Mr. Norman Scott-Russell. were, he believed, the Stockton and the Dewsbury and Batley, which were quite, or very nearly, level. He agreed with Mr. Parsons with reference to the great economy of having spare engines, but the argument was one which directors were slow to accept. There could be no doubt that if an engine were turned out in an unfit condition it would incur more harm in a day than from a month's ordinary work when in good order.

With regard to other mechanical power, he might mention the rope, compressed air, and electricity, the last of which he thought had hardly come within measurable distance of practicability. The rope had been worked with great success in America, and very well in this country, but it was a very different thing in America from what it was in England. Here the streets were tortuous, and there were great difficulties in regard to going deep into the ground. The streets being narrow, single lines and sidings, which were all against the use of wire rope, had to be adopted. For a very steep gradient, however, he thought there could be no doubt that it was the best, in fact the only, means of locomotion.

He desired to make an appeal to engineers, and also to the Board of Trade, in order that some arrangements might be made for a uniform gauge, and also a uniform width of car, as in Ireland. At present there were in England gauges of 2 feet 6 inches, 3 feet, 3 feet 6 inches, 4 feet, and 4 feet 8½ inches, and also different widths of car on the same gauge. On the 3 feet 6 inches gauge, for instance, there were widths of 5 feet 6 inches, 5 feet 9 inches, 6 feet, and even 6 feet 3 inches. He believed the present to be the commencement of a great era in tramways, which would form a network over the country and supplement the great system of railways.

Mr. Harris. Mr. H. Graham Harris said he should like to supplement the statement of Mr. Scott-Russell, as to the importance of tramways and tramway work, by pointing out that, according to a return just issued by the Board of Trade, £11,000,000 had been subscribed for tramway purposes in the United Kingdom alone; that nearly the whole of this capital had been expended; and that from the 30th of June, 1883 to the 30th of June, 1884, the tramways had carried 330,000,000 passengers. Those figures, he thought, were sufficient to show that the subject was an important one, and worthy the attention of the members of the Institution. Further than this the engineering question to be solved, in substituting mechanical for animal traction upon tramways, was not so easy a one as might appear at first sight. It was all very

Mr. Harris.

well to say, "There are thousands of examples of locomotives on ordinary railways, and all you have to do is to put a light locomotive upon a tramway; the work cannot be very great, two horses usually do it." It was no such easy thing as that. There were many important differences between traction upon the edge rail of a railway, and traction upon the grooved rail of a tramway. One of these was the difference of resistance to traction itself. Upon the edge rail of a railway, at the speed allowed by the Board of Trade Regulations for motor tram-cars, namely, 8 miles an hour, and on a level, the resistance to traction might be taken at 11 lbs. per ton. On the grooved rail of a tramway, at the same speed, it was more than twice as much, amounting indeed to 25 lbs. per ton of load moved, and in bad dirty weather, when the grooves were filled with road refuse, to 45 lbs. per ton. It would sometimes vary between those amounts, almost from hour to hour. He thought he could explain the reason, why the traction upon the grooved rail of a tramway should be so much greater than upon the edge rail of a railway. The tramway groove must be narrow, so that the ordinary street traffic might pass over it. The tramway wheel-flange must be wide, to give sufficient strength, consequently there was not much clearance between the two, and if there was the slightest incorrectness of gauge in the rail, or if the wheels were in the slightest degree out of gauge, there was a large amount of friction upon the sides of the flanges. Worse than that, the tramway groove got filled with road refuse, and the tramway wheel, instead of running upon its tread alone, was often running upon the edge of the flange as well, with the sides of the flange also rubbing against the sides of the groove; now owing to the differences of diameters of these portions of the wheels, they were, when the car was in motion, running at different speeds, and the result was that the resistance was increased, as compared with that upon the edge rail of the railway, where the flanges were clear of everything, from, as he had said, 11 lbs. per ton of load moved to about 45 lbs. per ton in bad weather. When, therefore, the motor for the tram-car was mechanical and was put upon wheels, the HP. required was something astonishing; with the weights given by Mr. Scott-Russell it amounted to about 38 indicated HP. With a 9-ton car upon an incline of 1 in 25 (which he took because it was capable of being worked by two horses), and at a speed of 6 miles an hour, the indicated HP. was as much as 25, and sometimes even more, because in the case of curves it was enormously increased. That was one of the troubles that the mechanical engineer who designed a motor tram-car had to deal with.

Mr. Harris. Two forms of car, the detached and the combined, had been described by Mr. Parsons, who strongly advocated the use of the detached car. He had, however, recommended Mr. Rowan's combined car, because, he said, it was possible to detach the body of the car from the engine and put it to another when required, so that the capital represented by the car-body would not be lying idle. At first that appeared to be an important consideration, but when it was remembered that the total cost of the combined car might be taken at £800, and the cost of the car-body itself at one-fifth of that amount, it would be seen that the saving effected by having a car-body capable of being put to two or three engines was very little. When, moreover, this saving of capital and interest, upon which so much stress had been laid, was taken in comparison with those on the detached engine, where it was necessary, according to Mr. Parsons, to have 33 per cent. of the engine-power lying idle, surely it was hardly worth consideration, especially when the question of extra complication which was involved was considered. It reminded him of what he had read in regard to the Great Western Railway. When the line was started, it was thought necessary to have the boilers of the locomotives capable of being detached from the engines, so that the boiler and engine might not be lying idle in the shed at the same time. Several engines of that kind, he believed, were made, but the necessary complication was so great, that it was not thought worth while to continue the system, and it was soon abandoned.

Reference had been made to the value of the cable system for steep gradients. He was himself interested in another mechanical method, the compressed-air system, of Mr. Mékarski, but he did not think that that, or steam, or anything else, would compare with the cable system for very steep gradients like those of 1 in 15 or 1 in 11, which were to be found on tramways. When the roads were in a dirty muddy state, the surface of the line became covered with mud, practically like butter, brought upon it by the ordinary traffic of the road, and upon this mud the sand used by the motor car was of very little use. In such a case, the cable tram, when the traction was not taken through the wheels on to the rails, and where the cable had only to pull the weight of the car itself, and of its load of passengers, was certainly the best that could be adopted. It might astonish the members to learn what the cost of sand sometimes amounted to for mechanical traction. On one line in London, where the steepest gradient was 1 in 25, it happened during one week last winter that the cost of sand for a single car amounted to two guineas, six loads of sand being used, at 7*s.* a load. That, he thought, was sufficient to prove that London mud at any rate was very difficult to deal with. **Mr. Harris.**

He agreed that the cost of working depended to a large extent upon the gradients, so that it was useless to give the cost of working a line without stating what the line was like. As to the cost of working an ordinary line by other systems than steam, he might be permitted to refer the members to the last volume of the Proceedings of the Institution,[1] in which a detailed statement was given as to the cost of working the Nantes line by compressed air on the Mékarski system; this cost would be found to be much less than that stated by the Author for working his ideal line by steam.

Mr. Norman Selfe said he had been travelling since last March, and therefore could not give any data on the Sydney tramways gained since Mr. Shellshear's Paper was written; but he had been in Sydney for thirty years, and had been familiar with the tramways ever since their initiation. He had also recently seen the cable roads of San Francisco and Philadelphia, the steam-locomotive roads in Glasgow and Leeds, and horse tramways in many cities. Mr. Shellshear's statements, based on official returns, could not be gainsaid, but there appeared to him to be a disposition to question his remark that the "Sydney steam-tramways were perhaps the most advanced in the world." The speaker, who objected to this claim, had an approving assent from the members generally, especially when he quoted the working expenses at 39·1*d.*, as against 9½*d.* on his line, without taking earnings into account. Of the Sydney tramways generally, it was never denied that they had proved a great convenience to the travelling public and to the residents in the suburbs. They had been extended so rapidly to meet the absolute wants of the people, that, seeing there was no precedent for the work, much of the road-laying had no doubt been done more than once, and the first cost was relatively much heavier than it was likely to be in the future. The demand for transit had at times been so great that he had seen engines drawing three hundred people instead of the one hundred and eighty for whom sitting accommodation was provided, the upper deck of the cars on such occasions being double-banked, and the footboards crowded. There was, for this reason, but little room for comparison between the Sydney engines doing such work on extremely steep gradients, and the engines **Mr. Selfe.**

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[1] Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 488.

Mr. Selfe. that he had as yet seen in England and Scotland, taking sixty passengers on comparatively level roads. As a friend had remarked to him, the tram-engines in this country were comparatively toys. To complete the comparison of the cost of working in Mr. Shellshear's statements with Mr. Parsons' ideal line of 16 miles, namely, 9¼*d.* against 39·1*d.*, when it was concluded that the Sydney system was behindhand, he would give the earnings:—

Mr. Parsons' line	12¼*d.*	Mr. Shellshear's .	49·96*d.*
Train-mile mean profits . .	3*d.*	„ .	10·86*d.*
Earnings per mile of line .	£1,660 to £1,675	„ .	£8,142
Earnings percentage on capital	6·6 per cent.	„	8·43 per cent.

He was not championing Mr. Shellshear's claim, but from these figures it would be seen that, under all the disadvantages of initiating a system of tramways 14,000 miles from the centres of civilization, with no precedents for the work, on steep gradients, and having also in many cases the expense of making and maintaining one-third of the whole roadway, the tramway engineers to the Sydney Government had brought a system into active operation which earned about five times as much per mile of line, and about 2 per cent. more on capital invested, than Mr. Parsons' proposed ideal line. On this account he believed Mr. Shellshear based his statement, and something more must be shown than had yet been done, before his claim could be discredited. With regard to the relative steadiness of rival engines, Mr. Shellshear recorded what he believed to be the fact, and what appeared to be supported by the experience of engineers elsewhere. The statement made by a speaker that the drivers in Sydney sometimes got sea-sick in consequence of the bad roads would, if true, apply to the heavy engines as well as to the light ones, and to those with a high pitch as well as to those with horizontal motion. That statement, however, might safely be passed over. As had already been mentioned, some portions of the line were laid with iron rails that had not much endurance, and, for a short time, no doubt one or two sections were inferior; but now, with concrete foundations, steel rails, and Australian hardwood cube blocks, both the road and the railway in the Sydney streets would safely bear comparison with the road and tramways in other cities. In San Francisco, which perhaps had the best tram service in the world, with both cable and horse-car roads on four separate lines in one street, and with the cars running on the cable roads at intervals averaging 1,700 feet, and often less than 1,000 feet, the roadway between the rails was simply cobble-stones packed in sand, and the

Mr. Selfe. ordinary traffic was allowed to get on the tram rails as much as it could without interfering with the tram traffic; for when on the stones, with holes 2 inches to 6 inches deep, it was subjected to rough jolting, and the stones were very prejudicial to the horses' feet. In Sydney, on the contrary, the blocks of seasoned hard-wood were laid on 9 inches of cement concrete to a smooth surface. In Paramatta Street, where the vibration of the sleepers made the blocks over their ends show a faint wave along the line, men were employed with adzes to keep the line smooth, and so great was the respect paid to the wheels of the buggies and other vehicles, that men were constantly employed making up the roadway level with the rails, where tarred metal or granite cubes were used for the road. There were gradients of 1 in 18 or 1 in 17, and in a 5-mile run there was an average gradient of 1 in 20 for about 1 mile.

Having said so much to show that there was some foundation for the suggestion that the Sydney tramways were "perhaps the most advanced in the world," and that it had not as yet been controverted, he might be permitted to state why experience did not favour the use of steam-locomotives for cities. It must be borne in mind that the connection of a city with its suburbs involved different considerations from those attending the internal traffic of the city itself. In the former case, the use of the steam-locomotive was often admissible, and a service with heavy loads, at less frequent intervals, to run for comparatively long trips, might meet the requirements. The steam and smoke were not in such a case relatively so objectionable, and there was plenty of scope for the future improvement of the steam-locomotive. But for connecting important points within a city itself, through narrow and crowded streets, between lofty buildings, where a service was desirable every two or five minutes, where large cars attached to a locomotive would be a great hindrance to the general traffic, and where, also, there might be a reasonable objection on the part of the passengers and residents to having the atmosphere further polluted by the products of combustion and steam (which, however much disguised to the eye, could always be smelt), there was perhaps more than one system of motive power for tramways better than the steam-locomotive. In May last there were six or seven cable roads in San Francisco, and another was being completed up Telegraph Hill, with a gradient in it, he thought, of about 1 in 3. Admitting it to be true, as stated by authorities in that city, that 50 per cent. of the engine power provided was employed to move the cable alone, and

Mr. Selfe. that the wear and tear were very heavy, still those roads were so successful that they were being copied in other cities, and as they fulfilled the conditions of being clean and noiseless, with the advantage of running often with single cars or short trains, and offered the minimum obstruction to ordinary traffic, no real comparison could be made between the cable system and locomotives for city use. The cable system, however, had some drawbacks. The great first cost, the wear and tear of cable, and other matters, were so serious as to have set American inventors at work, and it had been his privilege when in San Francisco, to be present at some very successful trials of the pneumatic-tramway system, invented by Mr. George Pardy of that city, a system which bade fair to eclipse the cable for ordinary grades, and to supersede the steam-locomotive where cleanliness, frequent trips, light loads, &c., were an object. The Pardy system was only slightly different from others that had been proposed before, but that slight difference made it a practicable one. Under Mr. Pardy's plan, stations were established at certain points adjacent to the tram route, where air was compressed to about 120 lbs. per square inch, and air-mains were laid under the roadway the whole length of the tram route. Only one main, however, was required for a double road. At every stopping-place on the route, and at such other stations and distances as might be desired, a special form of valve was connected to the main, which valve was accessible through a hole in the roadway about 3 inches in diameter, or less. The dummies, or engine-cars were provided with air-reservoirs under the seats, capable of withstanding 120 lbs. pressure per square inch, and had a small pair of engines capable of working the load with perhaps 20 lbs. pressure above the atmosphere, a reducing-valve and chamber being provided for the purpose. In the case of a dummy and reservoir-car being connected, their respective reservoirs were coupled by a flexible tube. The driver was provided with a stand-pipe and handle, the pipe having a flexible connection to the reservoir, and an oblong hole was made in the foot-plate. When the stoppage was made to put down or take up passengers, the foot-plate was brought over one of the openings in the roadway, and the insertion of the conical end of the stand-pipe into such opening through the hole in the foot-plate, opened a valve on the main and another in the stand-pipe itself, when the reservoir was charged up to 120 lbs. in, say, five seconds. On the withdrawal of the charging pipe the valves closed automatically, and the tram proceeded on its way without more time being lost for a re-charge than it took an ordinary passenger to alight or occupy a seat. As

Mr. Selfe.

the working pressure in the air-engines was very low, the power which might be saved by expansion from full pressure was not utilized, but all trouble of freezing at the exhaust was done away with; no supplementary fire was required, as with the Mékarski or other compressed-air systems; and the engine on the dummy, as compared with the highly compressed-air tramway locomotives, was simplicity itself. In running the engine-car or dummy alone, the driver could collect the fares, as was done with some of the horse tram-cars; but with a train of two or more cars a conductor was required, making then only two hands instead of the three or more for a steam-locomotive train. He made a number of trips on an experimental dummy built in San Francisco, and the results obtained were so successful that two omnibus companies made contracts for plant and outfit, and were about to open routes on the system, if they were not already started. This low-pressure compressed-air system presented no practical difficulties; no machinery in motion was required underground, and there should be a minimum of wear and tear. It was understood that the patentee expected to realize 30 per cent. of the power put into the compressor; but as much greater economy in coal consumption per HP. could be secured at a large station than was possible in a number of small locomotives, and fewer skilled engineers and other hands would be required than with steam-locomotives, it was just likely that the many advantages which this system possessed, in cleanliness, power of running small loads at frequent intervals, simplicity of repairs, and other features, would justify its adoption if only from 20 to 25 per cent. of the actual power developed in the compressor were utilized in the propulsion of the car and passengers.

The question of power depended, of course, very much on the proportion of dead-weight to passengers carried. On the Sydney tramways, according to Mr. Shellshear's Paper, it was, for an engine and two cars, 265 lbs. per passenger with one hundred and eighty persons seated, and it might be expected to be greater on the same system with smaller engines and loads if the gradients were as steep. He should be glad if Mr. Parsons would supplement his Paper by giving the weight of engine and car in his ideal road and estimate, and the maximum gradients proposed to be worked. In the pneumatic dummies to run ¾ mile on one charge, with a speed of 10 miles an hour, and carry twenty passengers, the weight was 6,800 lbs., or 340 lbs. per passenger, the gradient being 1 in 20; but with the addition of a reservoir-car to carry twenty more passengers, and weighing 4,500 lbs., the dead-weight was

Mr. Selfe. reduced to 282 lbs. per passenger, and the distance increased to 1¼ mile on the level. On the Clay Street cable-road in San Francisco the car and dummy, carrying thirty passengers, were said to weigh 5,650 lbs., or 188 lbs. per passenger, and of course had neither reservoir nor engine. It might be that they were made so strong because the gradients were in some cases as steep as 1 in 6, and lighter cars might be used now. The only data given to him of the weights of compressed-air tramway-engines, using a very high pressure, showed an 8-ton locomotive and a 3-ton car to fifty-six passengers, or about 440 lbs. per passenger, which was nearly double that on the Pardy system. The low-pressure compressed-air system had not yet had a long trial, like the more elaborate systems using pressures up to 1,000 lbs., and it would be very interesting to watch its future development. There were many openings for modifications in its use, as, for instance, in the case of a short steep rise, such as occurred in William Street, Sydney, where a small engine could be worked off the air-main to drive a supplementary cable, and help the cars over the difficulty.

Mr. Cotton. Mr. Francis M. Cotton observed that as early as 1872 the late Mr. John Grantham, M. Inst. C.E., introduced a combined steam-tramway engine car, which was constructed by Messrs. Merryweather and Sons of Greenwich; this car was capable of holding forty-four passengers, and weighed, when empty, 6½ tons. It was set to work experimentally on a short piece of railway at West Brompton, traversing the line at an average speed of 11 miles an hour. In 1876 this car was removed to the Wantage tramways, and had since been in constant use. This was quickly followed on the Wantage tramways by one of the Merryweather independent tramway engines, and Major-General Hutchinson, R.E., Assoc. Inst. C.E., of the Board of Trade, stated before a Select Committee of the House of Commons in March, 1877, that this engine was the only one he had then seen which was fitted with appliances having regard for the safety and convenience of the public. On the 17th of the same month, the Select Committee rode from Leytonstone to Stratford Church in a car drawn by one of these engines. In 1876 a steam-tramway engine was drawing five or six cars of passengers at the National Rifle Association Meeting on Wimbledon Common, and then in 1878 the Vale of Clyde Tramways were first worked by steam. In his opinion "the independent type" of engine (Plate 4) would be much improved if the cylinders were placed horizontally instead of at a considerable angle from the horizontal. It was well known that the nearer the cylinders approached the vertical in locomotives the greater would

Mr. Cotton.

be the oscillation on the road, especially with outside cylinders, and this well-established truth was fully borne out in tramway practice, but had been ignored by Mr. Parsons. Then again, for hard and constant work he did not like the gear. He thought none of the arrangements, where the motion was derived from the connecting-rod, were so good or lasting as the old shifting link-motion, provided of course the latter was made much stronger, and with larger wearing surfaces in proportion to the size of the engine, than would be used in ordinary locomotive practice, as so much more dust and dirt had to be contended with on tramways than on a railway. He should have preferred to have had the boiler and condenser rather larger, so that when running on the level all the steam would be condensed; in damp weather one-third of the exhaust steam escaping could not fail to be disagreeable. He understood that on some tramways only 50 gallons of water escaped uncondensed on a day's run, and the whole of this steam passed away on the inclines, none escaping on the levels. The most important point about a steam-tramway engine was the rapidity with which it could be brought to a standstill. Mr. Parsons seemed aware of this, for he had furnished his ideal engine with several powerful brakes. Mr. Cotton was therefore at a loss to understand the statement that the steam-engines were in frequent collision. In reply to an enquiry on the subject, he had received from Stockton-on-Tees a telegram to the effect that in the "course of more than three years only two collisions had occurred, and those had been due to drivers of vehicles being intoxicated;" also that no claims had been made. Table No. 1 (p. 115), would be very useful for reference. Although the cost per mile for working the engines was low, viz., 3·28*d.*, it was by no means the best result obtained by tramway companies. He had a record of the half-yearly running and repairs account for the engines (Merryweather's) of the Stockton and Darlington Steam Tramways, which gave 3·12*d.* per mile; and a similar account for the past twelve months of the Dewsbury, Batley, and Birstal Company (Merryweather engines) gave 2·57*d.* per mile run. This included cost of coke, oil and waste, water, firewood, locomotive repairs, drivers, coke, watering and relief man, and cleaners, and was, he believed, the best result hitherto obtained. These figures had been taken from the annual reports of the respective managers of the lines in question, and therefore demonstrated in a reliable and conclusive manner how economically street tramways could be worked. The latter line had been previously worked by horses when the cost was 5*d.*

Mr. Cotton. per mile. With regard to the question of repairs, Mr. Cotton thought that parts were made too light, and with insufficient bearing surface for the extra wear to which they were exposed. He also held that it must be an ill-conducted company that would allow the repairs to be done at midnight, or in the small hours of the morning by a labourer. In view of the approaching introduction of steam on the Metropolitan Tramways, some information as to what was being done in that direction might be of interest. The portion from Ponder's End, Enfield, to Edmonton, was laid; but the section along Seven Sisters Road to Finsbury Park had not been commenced. The North London Tramway Company obtained an Act to use steam-power on these lines last Session, having secured the sanction of the Board of Trade, and of the Metropolitan Board of Works. The line was intended to be worked by fifteen Merryweather engines. The cylinders of those engines were 7½ inches in diameter by 12 inches length of stroke, arranged horizontally inside the frames. The guide-bars and crossheads were of steel, and the crosshead-slippers were of cast-iron, with large wearing surfaces. The valve-motion was of the ordinary shifting-link type, case hardened. The eccentrics and straps were of cast-iron; these were made to a heavy pattern, for by this means the gear would run for eighteen months' continuous working without having to be set up, as had been ascertained in practice, so that the complaint against link-motion for tram-engines was not well founded, when proper proportions were employed. The coupling-rods had solid ends, bushed with phosphor-bronze; the wheels and axles were of steel. The boiler was of the locomotive type, made of mild steel; the fire-box was of copper. In addition to the feed-pump there was an injector which filled the boiler, and returned the overflow water back to the tank, thus economising water. Great attention was paid to the axle-boxes; their lubricators could be reached from the foot-plate whilst the engine was running, and they were fitted with dust-tight covers, so that the weak point in locomotives, namely, hot axles, was prevented. A fender-plate was attached to each end of the engine to obviate the possibility of running over obstacles. At Stockton-on-Tees, on a market-day, it was a common practice to force the engine through the crowd slowly, and no accidents had occurred from this proceeding. The condensers consisted of 1-inch copper tubes placed above the roof, and in addition to the air admitted to the front of the condensers, and made to pass through them, tapering air-passages were provided under the roof, and the air which passed in by these was found to disturb the hot air which clung to the tubes, thus making the condensers more efficient. A common practice existed of fastening the ends of the tubes by soldering, but in these condensers the ends were secured by ferrules, so that they could be repaired without pulling the apparatus to pieces. The boilers would work at a pressure of 150 lbs. per square inch, and all the requirements of the Board of Trade would be fulfilled. The weight of each engine would be about 8 tons when empty, and 9 tons when in working order, with water, fuel, &c. One of the most fruitful causes of wear in tramway locomotive bearings arose from the sand and dirt pushed or washed into the oil-cups by the driver when oiling; but this had been overcome in these engines, for the oil siphons were so arranged that the act of removing the cover cleared away all dust that might have gathered in the vicinity of the oil-hole. The first of these engines was expected to be at work on the North London line early in the year 1885. Mr. Cotton.

Mr. Joseph Kincaid wished to offer a few suggestions, based on the experience he had had with most of the engines made for street tramways. There were still serious complaints from the local authorities, as to the working of the condensers in certain states of the weather, and it was difficult to say how they were to be completely met. In the Kitson engine, which had given great satisfaction, the condensing was done nearly altogether by an air-condenser; in other engines water alone had been used, which certainly afforded much satisfaction as far as condensing the steam went, but it was very expensive. Great objections were made to it by the local authorities, because it was difficult in the streets to get rid of the hot water used in the condensers. He did not know how far that difficulty could be removed by the improvements made in locomotives. Another difficulty was the immense amount of wear and tear in consequence of the working parts being so close to the dirt, and the necessity of having them boxed in. In crowded towns in bad weather the wear and tear was very serious if the working parts were not carefully boxed in and raised above the roadway. The automatic-brake, as required by the Board of Trade, was accomplished in two ways, by a belt from the driving axle, and by a fifth wheel; but an objection to the belt arrangement was that when the wheels slipped the brake was put on. There were certain advantages in having a fifth wheel, and he should be glad if Mr. Parsons would give his opinion as to the mode of applying the automatic brake in that way. The speed-indicator used was in his opinion an unsatisfactory one. There had been three tramway engines at work Mr. Kincaid.

Mr. Kincaid. moved by compressed air, the Scott-Moncrief, Colonel Beaumont's, and the Mékarski. There had not been much experience with the Scott-Moncrief engine. Colonel Beaumont's engine worked at a very high pressure. The Mékarski had been in use for several years in Nantes. The fireless locomotive had been tried near Paris, on the tramway from Rueill to Marly on a severe gradient, and it was charged with superheated water. He did not know that the results had been satisfactory, and he understood that the system had been lately abandoned. He should be glad to know if it had been adopted in other places. Many engineers had been looking forward to electricity as applicable under certain conditions. Most of the members knew the great utility of the tramway in Brighton worked by that agency, which had also been adopted for the tramway at Giant's Causeway, where, however, it was applied in a different way. At Manchester also an experimental tramway was worked by electricity applied in yet another manner. Considerable advance was being made in the application of electricity to tramways, and it was to be hoped that some means might be found whereby it might be used at smaller cost. As to the cable system, of which he had some practical knowledge, especially as applied at Highgate, where the works had been designed and carried out by Mr. Eppelsheimer, he thought that it could be economically used in many places where the locomotive was not suitable. Not one of the systems, however, was of universal application. The cable system could not be economically successful if there was a very small amount of traffic, and on the other hand the steam-locomotive would not be of service in the case of very severe gradients. There was a great difficulty in applying the cable system in places where the roads were narrow and winding, but it might, he thought, be extended, getting rid as it did of the practical difficulty of the movement of a locomotive along public roads. It was hardly fair to compare the working of a tramway at Sydney with that of a tramway in this country, where the Requirements of the Board of Trade were very irksome in regard to the emission of steam and smoke, and that the rails used in a street should have a groove not exceeding an inch in width, necessitating an enormous power in the locomotive. The peculiarity of the Baldwin engine, he believed, was that it had a certain amount of elasticity suitable for very bad roads. That might have been the reason why it was highly valued in Sydney; but he did not know that it was a good reason for its adoption in this country.

Mr. Pritchard. Mr. Edward Pritchard observed that the engine which Mr.

Mr. Pritchard. Parsons had described was working very well; it met the Requirements of the Board of Trade, and had been advantageously adopted by various companies, judging from the dividends paid to the shareholders. There were one or two points, however, which he proposed to challenge. It had been stated that it was important to have good brakes; but that was a matter which the Board of Trade had determined. He agreed with Mr. Parsons that it was very desirable that the driver should know when the brake was in perfect order; but when upon a severe incline the driver's attention had to be directed to the brake fifteen or sixteen times, he thought the service rendered by the brake was not so great as it might be. He would suggest that engine-makers should still consider the best means of putting the brake in operation. With a severe gradient and a slippery road, it certainly did not operate as it should, and it caused excessive expenditure in working the line. On an easy road, or with a clean rail, it only came into operation when the maximum speed was exceeded; but under other circumstances the result was very different. As to the employment of sand, he might remark, that it was so necessary on one line with which he was professionally connected where the gradients were severe, that he was about to place a small trolly to supply the sand to the rail. Drop-points were no doubt injurious to the life of the engine, seriously affecting the springs, and frequently the wheels themselves; but that evil, he believed, was in a fair way of improvement by the adoption of a movable toe. There was one method of construction, where the point gave way under the weight of the engine passing upon it, and was replaced by a spring. There was also another, where the point was actuated by the dead weight. How these points might act, he was of course unable to say; but he believed that the method would be found to be a considerable improvement upon the ordinary drop-point. The question of the cost of working, and the receipts per mile run, had attracted considerable attention; in fact unless tramways were made to pay, they would not be held in much favour by a certain portion of the population. It had been stated by Mr. Parsons that the cost was 9·33*d.* per mile. He had not given the gradients of the line; but Mr. Pritchard was acquainted with a line in which those figures closely represented the actual cost. Although there was a length, probably 30 chains, of 1 in 22 or in 23, the cost named had not been exceeded. He had also the experience of another line, where there was a difference of level of 475 feet in 5 miles, giving a prevailing gradient of about 1 in 58. The chief gradients were

Mr. Pritchard. 1 in 15 for 10 chains, 1 in 16 for 12 chains, and 1 in 18 for 20 chains. The Kitson engines succeeded on that line, and that was the line to which he referred in alluding to the erratic action of the automatic brake, and also to the sand arrangements. The cost of working upon that line for the last five months had been 11·1*d*. per mile, and the receipts for the same period amounted to 17·79*d*. per mile. A comparison had been drawn between tramways in Sydney and in England, and a misapprehension, he thought, had existed with reference to the cost per train-mile. The proper course to adopt would be to take the cost and the receipts, and ascertain the surplus. He should be glad to know why in Sydney, where it was supposed that something like perfection had been attained with a much lighter rail than the one used in England, the cost should have been about £15,000 per mile, inclusive of equipment. That was certainly very much in excess of the cost of construction of lines in this country. The percentage of earnings on the capital for 1882 in Sydney amounted to 5·6, but in England there were lines with earnings far in excess of that amount. It was also stated that in Sydney it was common for three hundred passengers to ride upon cars constructed to carry ninety. He had been informed that deaths due to tramway accidents in Sydney were numerous; he should like to know if the death-rate of the city due to such accidents could be given.

Mr. Crampton. Mr. T. R. CRAMPTON was sorry that during a recent visit to San Francisco he had not seen the compressed-air apparatus. The engineer of the cable line took him over the whole of the system, and he could not imagine anything superior; but the cost of it was enormous. The last line was constructed on a gradient of 1 in 8 or in 9, and the company made their own cables, supplying a new one every fourteen months. Everything was of the best quality, and the total cost was $120,000 per mile. The other systems had not cost so much, but on the tramways to which he referred everything was done in the most substantial manner. The carriages were open and very light, and the people jumped on to them as they pleased in a way that would not be permitted in England. It was not surprising, therefore, that accidents now and then occurred. The Board of Trade would certainly not allow companies in England to carry the same number of passengers. He thought that too much attention was being paid to engines, and not enough to roads. If the roads were made sufficiently good for the ordinary traffic passing over them they would be strong enough for any engines that could be put upon them. It was absolutely

Mr. Crampton. necessary that engines should be kept separate from the carriages, where the traffic was large, and the wheels should be as close together as possible. There was one thing especially against which locomotive engines should be guarded. It had been stated that the Baldwin engines at Sydney ran steadily with horizontal cylinders, and that the Kitson engines did not. This might be so, particularly when the wheel-base was small, and the roads bad. He had no reason to change the views which he had expressed in a Paper presented by him to the Institution in 1849,[1] in which he had discussed at some length the question of the causes of oscillation in locomotive engines. He then showed for the first time how engines could be constructed having every working part without exception within sight, nothing being under the boiler. He also showed the effect of the angle of the connecting-rod in assisting oscillation. He placed the front wheels of an engine constructed upon his system (with driving-wheels behind the fire-box) on a weighing machine, the others remaining on the road, when, turning on full steam, the weight on the front wheels was relieved of 6 cwt. only, and on treating an ordinary engine having driving wheels in the centre in a similar manner, a load of 24 cwt. was taken off. This alternating weight tended to cause oscillation, which increased when the locomotive ran on bad roads; therefore, where convenient, the connecting-rod should be as long as possible, and the vertical thrust should be directly under the centre of gravity of the engine. Engines should be constructed to work steadily on bad roads. It had been stated that high engines ran more steadily than low ones. He imagined when such results were noticed that a well-constructed high engine was travelling on good roads, and a badly-constructed low engine on bad roads. It could hardly be seriously contended that high engines would not swerve more than low ones, the condition of the roads being the same. He should not wish it to be understood that he thought the Kitson engine would not answer its purpose well. Engineers had many circumstances to take into consideration in designing engines, and they could not in all cases adhere to strict principles.

Mr. Price-Williams. **Mr. R. Price-Williams** said Mr. Parsons had stated that the first Act for the construction of tramways on public roads was so recent as 1870; whereas an important Act had been passed ten years earlier for Ireland, which had served as the basis of a great deal of subsequent legislation in connection with the subject under

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[1] Minutes of Proceedings Inst. C.E., vol. viii., p. 233.

Mr. Price-Williams. discussion and as there were some special features in connection with this Act of 1860, he would briefly advert to it. Powers were given under the Act to the Grand Juries in the Counties in Ireland to facilitate the construction of tramways, and Joint Stock companies were authorized to deposit plans in the ordinary way, and to submit them to the Grand Juries, who were empowered to inquire into the merits of the schemes, and could give their approval and make "presentments" to the Lord-Lieutenant, who might by an Order in Council give it the sanction of law, subject to the obtaining of an Act of Parliament. Compulsory powers were also given to acquire land within 30 feet from the centre of the roads, and altogether great facilities were afforded for the construction of tramways. Unfortunately, however, the requirement of an Act of Parliament, after the sanction of the Lord-Lieutenant had been given, was fatal to the measure. In the next year an Act was passed removing the necessity for applying to the Imperial Parliament for a confirmation. Nothing, however, resulted from this Act for some time; but in 1871, four years prior to the period mentioned by the Author as the time when mechanical power was first authorized for English tramways, authority was given by an Act to employ mechanical power on these tramways; the speeds were limited to 6 miles an hour on roads, and 3 miles an hour in towns. Another Act in 1881 followed, which gave power to increase the speed to 10 miles. But after all this legislation, little progress was made until some advance occurred in England. In 1883, however, a great departure was effected, and power was given to the Grand Juries in Ireland, under a short Act passed at the end of last session, to give guarantees; the Imperial Government also contributing something like 2 per cent. of the cost. Under the influence of that Act, during the last year or year and a half, a considerable mileage of light railway had received the sanction of the Grand Juries, and in some cases the sanction of the Lord-Lieutenant or Order in Council. He particularly referred to the subject, because he thought the time had come when an Act of this kind was urgently wanted in England. The late Mr. Vignoles, Past-President, in his inaugural address in 1870, laid stress upon the fact that there were 160,000 miles of metalled roads in the country, and Mr. Price-Williams found, from a reference to returns made in 1831, that there were about 25,000 miles of public roads and turnpike roads. Many of those turnpike roads ran parallel with and close to the great arterial lines of railway, but at least 12,000, or 15,000 miles, which traversed important agricultural districts at a considerable

Mr. Price-Williams.

distance from any railway, were in every way adapted for the construction of light railways; and if the same powers were given in England for facilitating the construction of light railways and tramways as were given in Ireland, there would, he thought, be a new and important means afforded of supplementing the great arterial lines of communication in the country by valuable tributaries. The distinction in Ireland between a light railway and a tramway was simply this, that a tramway was considered to be entirely on a public road, and a light railway on private ground. If a tramway was constructed on a public road or highway more than 18 feet from the side of the road, it was free from all restrictions of the Board of Trade with regard to levels, and land could be acquired compulsorily except where domains were passed through. If similar powers were granted in England, large districts at present entirely without railway communication would be put directly in connection with the trunk lines, and the new lines would serve as valuable feeders to the branch lines. With regard to the question as to whether they would pay, he might mention that of the 260 miles of light railways and tramways in Ireland, with which he was concerned as consulting engineer, about 100 miles had already been sanctioned by the Grand Juries, and the whole of the capital for their construction found, the average cost not exceeding £4,200 per mile. Table I. (pp. 151, 152) was a statement showing the full particulars of the cost and other details, including the probable revenue. As regarded the paying character of light lines, in all cases in Ireland it had been necessary to satisfy the Grand Juries that there would be a fair prospect of their proving remunerative, because, notwithstanding the great inducement to the employment of capital (chiefly English), afforded by the Imperial and Baronial guarantees, the Grand Juries were very sceptical as to the paying character of the lines. Under his advice, the promoters of the lines had employed a staff to ascertain the amount of traffic in the district. With the view, however, of checking the estimates made by these observers, he had adopted a novel plan, which he thought would commend itself as being safe and reliable, and which he had found of great use. Fortunately there existed in Ireland what was wanting in England, namely, most accurate statistics in regard to the population and rateable value of every parish, township, and barony throughout the country; and it had occurred to him, that, in order to test the amount of traffic in a district unserved by a railway, population might afford a good basis. He had, therefore, accurately defined the gathering-ground of each district.

Mr. Price-Williams.

TABLE I.—TRAMWAYS and

Name of Line.	—	Length in Miles.			Estimated Cost including Equipment.	Estimated Cost per Mile.	Area of District.
		M.	F.	Ch.	£.	£.	Sq. Miles.
Wexford and New Ress .	T. & L. Ry.	32	7	3	144,975	4,405	292
Galway, Oughterard, and Clifden (including Roundston Branch) .	Light Ry.	53	4	0	210,000	3,925	821
Athboy and Castle Pollard	T. & L. Ry.	18	2	9	73,783	4,017	160
Portarlington and Mountmellick	”	9	0	6	38,546	4,249	58
Maryborough and Stradbally	Tramway	7	1	6	29,143	3,848	65
Mountrath	T. & L. Ry	3	1	8	15,726	4,483	43
Ballybrophy and Rathdowney	Tramway	4	0	4	19,658	4,700	43
Craughwell and Loughrea	T. & L. Ry.	7	1	0	23,777	3,338	126
Carrick - on - Suir and Callan	Tramway	14	6	4	64,652	4,369	149
Castle Comer and Athy .	T. & L. Ry.	18	6	2	75,825	4,050	155
Virginia and Ballyjamesduff	”	12	0	9	62,660	5,200	144
Foxford and Ballaghadareen	Tramway	26	1	7	94,994	3,700	313
Dromkeen, Cappamore, and Doon	T. & L. Ry.	7	0	3½	33,103	4,729	67
Nenagh and Thurles .	Tramway	23	0	0	94,282	4,100	157
Nenagh and Shannon .	”	10	0	0	43,370	4,337	51
Kilmainham and Bailieborough	”	10	3	7	60,000	5,736	107
		258	1	8½	1,084,494	4,200	2,751
Total of Irish Railways, 1882		2,465	0	0	34,962,665	14,184	32,524

Mr. Price-Williams.

LIGHT RAILWAYS (IRELAND).

Population of District.		Rateable Value of District.	Railway Traffic Value of District.		Estimated Traffic Receipts of Proposed Light Railway and Tramway.				
Total Population Served.	Population per Sq. Mile.		Annual Value.	Per Mile per Week.	Annual Gross Receipts.	Per Mile.		Annual Net Receipts.	Interest on Cost of Works and Equipment of Line.
						Per Annum.	Per Week.		
Number.	No.	£.	£.	£.	£.	£.	£.	£.	Percent.
43,841	150	127,300	25,460	14·9	12,730	387	7·44	8,487	5·85
87,846	107	125,480	25,096	9·1	16,730	319	6·12	11,153	5·30
17,418	108	82,570	16,514	17·6	8,257	458	8·80	5,505	7·46
6,732	117	20,125	4,025	8·5	2,683	296	5·68	1,788	4·64
8,005	123	28,515	5,703	13·3	2,852	345	6·63	1,901	6·52
3,879	90	12,208	2,442	14·6	1,221	379	7·29	814	5·18
4,225	99	18,825	3,765	18·0	1,882	470	9·00	1,255	6·38
10,495	83	31,621	6,324	17·1	2,108	296	5·69	1,405	6·00
19,711	132	73,497	14,700	17·3	7,350	450	8·66	4,900	7·58
19,893	129	65,170	13,034	12·4	6,517	323	6·21	4,345	5·73
24,891	173	67,005	13,401	21·3	6,700	553	10·63	4,467	7·14
46,850	149	56,431	11,286	8·3	7,524	287	5·52	5,016	5·28
8,780	132	22,600	4,520	12·3	2,260	321	6·17	1,507	4·55
17,749	113	58,151	11,630	9·7	7,753	337	6·48	5,170	5·48
5,155	101	14,160	2,832	5·4	1,888	189	3·63	1,259	2·90
18,791	175	44,106	8,821	16·2	4,411	222	8·11	2,941	4·90
344,252	125	847,764	169,553	12·7	92,866	362	6·06	61,913	6·07
5,412,377	166	13,420,022	2,772,585	21·5	..	..	..	..	..

Mr. Price-Williams.

TABLE II.—DEPRECIATION OF LINE. ROLLING STOCK.

—	First Cost.	Annual Depreciation.	Period of Sinking Fund, 3 per cent. compound interest.	Annual Cost per Train-mile.	Ordinary Maintenance Cost per Train-mile.	Total Maintenance and Depreciation per Train-mile.	Total Annual Cost.	Annual Cost per Engine and per Carriage.	Money Life.
	£.	£.	Years.	d.	d.	d.	£.	£.	£. Years.
Line .	72,000	2,160	23	0·99	0·15	1·14	2,471	..	$\frac{72{,}000}{2{,}471} = 29\cdot14$
Buildings	4,000	100	26½	0·05	$\begin{Bmatrix} 0\cdot29 \\ 0\cdot09 \end{Bmatrix}$	0·43	932	..	$\frac{4{,}000}{932} = 4\cdot29$
Engines	19,500	1,950	8¾	0·90	0·80	1·70	3,684	147·36	$\frac{780}{147\cdot36} = 5\cdot28$
Cars .	6,250	625	8¾	0·29	0·26	0·55	1,192	47·68	$\frac{250}{47\cdot68} = 5\cdot23$
Tools .	2,000	100	16	0·05	nil.	0·05	108	..	
	103,750	4,935	16½	2·28	1·59	3·87	8,387	..	Average Years. $\frac{103{,}750}{8{,}387} = 12\cdot37$

TABLE III.—THREE PER CENT. SINKING FUND for RENEWALS.

—	First Cost after deducting Scrap Value.	Period of Sinking Fund, 3 per cent. compound interest.	Sinking Fund, 3 per cent. compound interest.	Cost per Train-mile.
	£.	Years.	£.	d.
Line and works[1]	52,736	25	1,446	0·67
Buildings	4,000	40	53	0·02
Engines (less 15 per cent. scrap) . .	16,575	15	891	0·41
Cars (less 10 per cent. scrap) . . .	5,625	10	491	0·23
Tools	2,000	5	376	0·17
	80,936	18¾	3,258	1·50
[1] Average cost of line per mile (see Table, p. 114)	£. 4,521			
Deduct— £. s. d. Excavation . . . . 717 10 0 Scrap value of permanent way, 127 tons at £4 . 508 0 0				
1,225 10 0	1,225			
	3,296	Miles. × 16	£. = 52,736.	

Mr. Price-Williams.

He found, however, that the population basis was not reliable; and that the rateable value, as indicating the commercial activity of a district, would be more likely to be the gauge of what the actual traffic would be. He had ascertained, in the first place, that the ratio of the entire rateable value throughout Ireland to the entire railway traffic receipts in Ireland was roundly about 5 to 1, and that this ratio was of a very constant character. In other words, given the rateable value of a district at present served by a railway, the railway traffic receipts in that district would be about one-fifth of such rateable value; and he might mention that he had been able practically to test the reliability ot this rule, by ascertaining the rateable values of certain well defined areas, such as those served by the Dublin, Wicklow, and Wexford, Cork and Bandon, and Dublin and Meath, railways.

He was glad to have an opportunity of bearing testimony to the way in which the Kitson engines worked; they were eminently suitable for street traffic. With reference to the inclination of the cylinders, although Mr. Crampton was theoretically right, practically the matter was of no moment. He need not go further than the Metropolitan Railway close at hand, where the system was generally adopted. With reference to the plan of condensing steam, he could also bear testimony to the complete way in which that was done; he had had an opportunity of testing Mr. Wilkinson's engine for superheating it, and so far as getting rid of the steam was concerned, it entirely effected its purpose. He exhibited a table to show that Mr. Parsons was in error, in including in his depreciation fund the entire cost of the line and works, and that in such items as permanent-way and rolling stock, subject to wear and tear, and for the renewal of which provision should be made in the early years of the working of a line, credit should be allowed for the scrap value. The total sum for which a sinking fund had been provided by Mr. Parsons was £103,750 (p. 113), and the total annual amount allowed for a sinking fund was £4,935, which at 3 per cent. compound interest, would provide for the renewal of the entire line, buildings, engines, and rolling stock generally, in the short average period of sixteen years and a half (Table II.), the annual amount set aside for the renewals of the engines and rolling stock being sufficient to renew them entirely, irrespective of the credit value of the scrap, in the short period of eight years and three quarters. If in addition to the sinking fund, the amount per train-mile provided under the head of ordinary maintenance was added, it would be found that the total annual sum provided would represent an average "money

Mr. Price-Williams. life" for the whole of the undertaking (exclusive of the cost of the land) of only twelve years and four months (12·37). In other words, the annual amount provided for the sinking fund and for ordinary maintenance would represent its first cost in that short period; the "money life" in the case of buildings, amounted to the exceedingly short period of four years and a quarter, and only five years and a quarter in that of the engines and rolling stock; whereas the average money life of engines on the principal lines of railway in England and Wales during a long period of years was about ten years.[1] The amount allowed for depreciation was obviously excessive. In Table III. (p. 154) Mr. Price-Williams had shown, that after deducting the cost of constructing the line, and making allowance for the scrap value of the old materials of the engines and rolling stock, the amount of the items, subject to depreciation, would be reduced from £103,750 to £80,936; and that the period over which the sinking fund would operate, would be extended, in the case of the engines, from eight years and three quarters to fifteen years, and to ten years in the case of the cars. The cost per train-mile of the whole of the items included under the head of depreciation, as given by Mr. Parsons, was 2·28*d.*; this would be reduced to 1·50*d.* per train-mile (Table III., p. 154). In the case cited by Mr. Parsons, the amount of the train-mileage was very large, and Mr. Price-Williams thought there was nothing so unreliable as train-mileage, when not considered in connection with all the circumstances of the particular traffic. In this case its effect as a very big divisor on these items of depreciation made their cost appear very small, whereas in reality, as he had shown, they were excessively large.

Mr. Wilkinson. Mr. WILLIAM WILKINSON desired to offer a few observations on three matters,—the motive-power, the "drop-off" point (this destructive element to engines), and the slipper-brake. He had been trying some experiments with the slipper-brake. He had a model with the wheels and axles accurately turned up and made as frictionless as possible, and taking this model with the wheels skidded, tried the following experiments. At what he termed the angle of repose, the machine would neither slide nor be quite steady; if it was touched or blown, it would move ¼ inch, and then come to a state of rest. That was at a gradient of 1 in 8. At a gradient of 1 in 7·75, it would gradually slide down hill. Applying the slipper-brake, Fig. 7, in the same way, the results were similar. He, therefore, contended that the advantages generally

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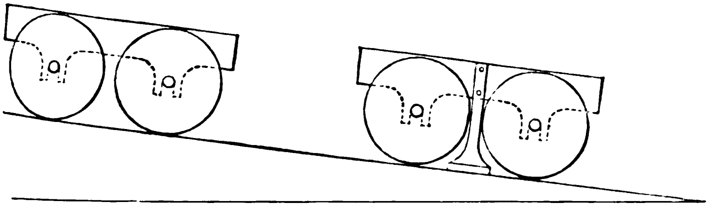
[1] Minutes of Proceedings Inst. C.E., vol. xxx., p. 151.

Mr. Wilkinson.

thought to follow from the application of the slipper-brake did not exist; indeed, he believed it to be an element of danger. With reference to points, he had brought an illustration of a single spring point on the Wigan tramways (Fig. 8). It was a piece of steel riveted fast to the point plate, and as the engine went over, it was sprung open and immediately snapped to again. It had been working for some time at Wigan without the slightest mishap, no engine ever having gone the wrong way. With the drop-off points the engine frequently went one way and the car the other, with very bad results. The simplicity of this point was its principal recommendation. He thought he was the first to attempt to ascend such steep gradients as 1 in 13, and 1 in 12, and 1 in 11½ by steam power, so that he could speak with some little authority on the subject. An engine of his had been before the public for three years, and since then one hundred and fifty of these engines had been built, and were working in various parts of the kingdom, from Gateshead in the North to Plymouth in the South, with some measure of success. That success had been mainly in proportion to the care taken with the engines and the skill brought to bear in the management of the mechanical department on the various tramways on which they had been adopted. Where there was a surplus of engines, so that they could be repaired and kept clean, they had worked very well, but in other places where there had been a deficiency of engines they had failed. He had had considerable experience of the shortcomings of this engine, and he thought there was plenty of room for improvement in working

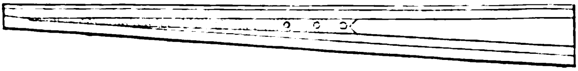
Fig. 7.



Scale $\frac{1}{24}$.

Slipper Brake.

Fig. 8.



Spring Point on Wigan Tramways.

Mr. Wilkinson. steep gradients at low speeds according to the Board of Trade Regulations. The result was that he had designed another engine to which he now directed attention (Plate 5, Figs. 3 and 4). He had departed widely from the ordinary method of locomotive engineers by adopting a worm-gear, of which it had been prognosticated that it would be an utter failure; but he was proud to say that it was not an engine on paper alone, but one that had been built and which was giving very satisfactory results. It was prophesied that when the steam was shut off from the steam-pistons the worm and the wheel would lock and the engine slide on the rails, but no such thing had happened. A gradient of 1 in 70, which was considered slight in tramway practice, would propel the worm round by the force of gravity. It had also been prognosticated that there would be an undue amount of friction, but that, too, had proved erroneous. No doubt with the old cast-iron worms and worm-wheels there would be, but now that better materials were available, such as phosphor-bronze and steel of various kinds, the case was different. The worm he had used was constructed of Siemens steel, and the worm-wheel ran in an oil bath, so that there was constant lubrication, the oil being carried to the worm and back into the bath with very little waste. To show that there was no undue friction, he might state that the engine would draw a loaded car, weighing 3 tons and as many passengers as could be crowded into it, on a level or nearly level road with the valves in mid-gear, after it was once started. The steam was cut off at one-eleventh of the stroke. Another strong point in its favour was that the cylinders, slide-bars, valve-gear, foundation-plate, worm, plummer blocks, &c., could be all removed from the engine as a whole machine in about two hours by taking away six bolts; and a duplicate engine could be put in its place in the same time by screwing up the same number of bolts. The engine could be left on the workshop floor for repairs, and then go out again to do its duty with the duplicates, instead of having to remain idle.

There was another point in the boiler to which he should like to direct attention. A few years ago the late Mr. Dewrance of Liverpool tried a series of experiments with a multitubular boiler 66 inches long. He divided it transversely into sections each 1 foot long, except the first section against the fire-box tube-plate which was only 6 inches. He found that the first 6 inches of tube, including the fire-box tube-plate, evaporated more water than the whole of the 60 inches length of tubes besides. Acting upon that Mr. Wilkinson designed a short locomotive boiler with tubes only 1 foot long. His object was not to interfere with the water-level

Mr. Wilkinson.

in the boiler in going up such gradients as 1 in 11, 1 in 12, 1 in 13, or 1 in 14, as it had been interfered with in the case of the long locomotive boilers. Owing to the trouble that had been experienced in torpedo-boat boilers, with the leakage of the tube-plate through the large range of expansion or contraction in the tubes, he knew that straight tubes would not do, and he therefore put the tubes into a reversed curve so that they would be able to yield a little. He conveyed the exhaust steam from the engine into a condenser which had between 200 and 300 square feet of effective cooling surface. He drew all the atmospheric air to support combustion through those tubes into a closed ash pan. He did not know whether the method was original; he was inclined to think that he had been anticipated in it. All the steam that was not condensed passed into a super-heater with tubes exactly coincident with the boiler tubes, and the gases passed through the super-heater into the smoke-box. When the engine was running on a level with a heavy load and working in mid-gear as nearly as possible, there was such an amount of expansion that the condenser condensed the greater portion of the steam. There was scarcely any steam left of sufficient tension to give the artificial draught required to support combustion. He had, therefore, designed a variable blast pipe, somewhat different from others that had preceded it. These had a cone inside the pipe, by raising or lowering which the annular space was reduced or increased. That would not do, and he had designed a cap, fitting over it like a valve. It was worked from the outside of the smoke-box with a lever. Under a high rate of expansion the cap could be closed, and the area of the blast-pipe reduced to about one-half of its original sectional area, so that what little steam was left increased the blast slightly, and supplied about the right amount of steam. He had also introduced "Field" tubes between the stay girders, or the roof bars of the fire-box. It was no doubt well known that the "Field" tube was very effective for the generation of steam. With reference to slipping on steep gradients, when engines of the ordinary type slipped, they really did slip. He did not say that his engine would not slip, but it slipped slowly; such a rate of piston-speed could not be got up as would make the wheels fly round; the steam was kept on all the time, and by a little sand the slip could be easily arrested. With the ordinary locomotive on a steep gradient, if the steam was shut off to arrest the slip, the engine stopped, and could not start again. Another point had been argued, namely, that there would be an excessive rate of piston-speed in the engine; but at

Mr. Wilkinson. the regulation speed of 8 miles an hour, the piston-speed was only 436 feet per minute, and there was scarcely any express locomotive that did not run at considerably more than twice that speed. He had driven the engine 16 miles an hour in order to test it. He had paid attention to accurate balancing with favourable results. He had further increased the diameter of the driving wheels, up to and above 36 inches, as against the ordinary standard type of tramway-engine wheels. That increased the life of the tires, which was an important item in the working of tramways, owing to the extremely dirty state of the roads, as compared with the clean raised road of an ordinary railway. Again, the increased radius of the wheel, owing to the increased diameter, had a beneficial influence on points and crossings. The less the diameter of the wheel, and the smaller the radius, the more likely it was to take off the tips of the points in crossing.

Mr. Greig. Mr. ALFRED GREIG said that Messrs. John Fowler and Co., of Leeds, had decided a few months ago to manufacture steam tramway-engines. In designing the tramway-engines to meet the Board of Trade Regulations, they had found that there were innumerable difficulties to overcome, of which the two principal were how to maintain a sufficient chimney draught in the absence of exhaust steam, and how to get rid of the exhaust steam without noise, or without its being visible. The first of these conditions had been dealt with by Mr. Parsons, who had stated "about two-thirds of the steam which escapes from the engine is condensed in this way, and the remaining one-third is allowed to pass into the chimney to improve the draught." He quite agreed that one-third would help to maintain the draught; but he could not understand how steam would not show itself in cold or damp weather, however little might escape. Mr. Greig had been compelled to seek some other means of creating the draught, which he had succeeded in doing. Condensing was, he thought, a more difficult thing to get over. Mr. Parsons had stated: "Efforts have been made to economize the consumption of steam in tramway-engines by compounding the cylinders, and in this way not only to reduce the consumption of fuel, but also to avoid to some extent the difficulty of rendering the exhaust steam invisible. The results of experiments so far have not been very successful, and the Author is of opinion that little economy can be effected with an arrangement of this kind. There is also considerable difficulty in starting a compound tramway-engine quickly. To obviate this several ingenious contrivances have been invented; but on the whole a simple high-pressure engine, like the one already described, meets the requirements most satisfactorily." **Mr. Greig.** He should like to know on what grounds Mr. Parsons based this opinion. The engines now being constructed by Messrs. John Fowler and Co., for the Brighton Tramway Company, were provided with compound cylinders, not only to economize the fuel, but to aid in dealing with the exhaust steam. He might not have made that departure from the usual practice had it not been for his experience during the last four years with compound traction-engines, of which some hundreds were at work in England and abroad. There was a saving with those engines of from 25 to 30 per cent. in the fuel as compared with single- or double-cylinder engines. As to the starting of the compound engines no complaints had been received; on the contrary they had been found more easy to get out of holes than others. He had made two compound locomotives and had had no difficulty whatever in starting them. His father, who had lately returned from Australia, had seen in Sydney the compound tramway-engines, manufactured at the Baldwin Locomotive Works, Philadelphia, having four cylinders, one high- and one low-pressure at each side placed tandem, and they were doing their work satisfactorily. From recent experiments with air-condensers applied to compound agricultural engines, he had found the exhaust steam much easier to deal with than with the ordinary high-pressure engines. A third difficulty to be overcome, in order to meet the Board of Trade Regulations, was one which cost manufacturers no little trouble, namely that they were required to fit their engines with an automatic-brake which could not be tampered with by the driver. To overcome that difficulty, as far as manufacturers were concerned, and also to remove the excuse so frequently made by the driver, the failure of the automatic-brake, he would propose to reverse the regulation and place something on the engine that would tamper with the man. Having met all the Requirements of the Board of Trade, manufacturers had next to take into consideration the wear and tear which tramway-engines were subjected to. From his experience with agricultural traction-engines and road-locomotives, he was of opinion that in order to reduce the wear and tear to a minimum, not only should the wearing parts be kept as far from the rail as possible, but the wearing surfaces should be excessive, almost twice as large as in an ordinary locomotive. Taking into account the extra expense incurred by having to comply with the Board of Trade Regulations, and considering the extraordinary conditions under which the engines were worked, he thought that tramway com-

Mr. Greig. panies should regard the first cost as a secondary consideration, and allow the makers a sufficient sum to permit them to supply an engine suitable for tramway traffic. That would be a much less costly method of dealing with the wear and tear than by having a large percentage of spare engines, necessitating large buildings, and also extensive repairing shops.

Mr. Lewis. Mr. W. B. Lewis said it might be interesting to the Institution to know, that light railways in Sydney, with the tram-cars running at 10 miles an hour through the streets, could not exist without some danger to the public. He had seen the Government Report for the year 1882, alluded to in Mr. Shellshear's Paper, and he had found that in that year on the 22 miles then in operation, eight persons had been killed and forty-eight injured. Of the killed, one was a servant of the company, a conductor who was accidently knocked from the tram-board by a passing dray; three were passengers who contributed to the loss of their lives by attempting to enter or leave the cars when moving; and four, two children and two men, were run over. Of the forty-eight injured, five were servants of the company, twenty-eight were passengers, and fifteen were described as "others." That was a state of things which the Board of Trade would not permit in England. He rather objected to the passage in Mr. Shellshear's Paper, wherein it was stated that the steam-tramways in Sydney were "perhaps the most advanced in the world"; because their cost had been very great, and their construction was not yet satisfactory. The Paper did not give the total cost, for he had found that there was a sum of £14,325 which would have to be added to that named by Mr. Shellshear, who took only one-seventh of the cost of the last steel rails, which had been substituted for the two former sets of rails that had failed. With that addition he found the total amount spent was £426,886, or at the rate of £19,404 per mile—a large sum for railways in the Colony. In New South Wales at the end of 1882 there were in existence 1,268½ miles of railway, which had cost on an average £12,490 per mile, and in Victoria there were 1,562 miles of railway, which had cost £13,757 per mile, the cost of the tramways having been more than either. Some of the railways were double and some single, but the majority were single. On the railways in New South Wales the earnings per train-mile were 7*s.* and the expenses 3*s.* 10¼*d.* In Victoria the earnings were 6*s.* 8*d.* per train-mile, and the expenses 4*s.* 5½*d.*; on the tramways the earnings were 3*s.* 9*d.* and the expenses 3*s.* 1*d.* It might be true that train-mileage was a fallacious basis of comparison, but it

Mr. Lewis.

seemed to him remarkable that there should be such a large sum as 45*d.* per train-mile earned on a tramway, by a little load consisting of a single carriage with passengers. One fact, which bore on what Mr. Price-Williams had said, was that where there was a population on either side of a road wishing to get up at one point and down at another, tramways paid admirably, but in a sparsely-peopled district he doubted whether they could be made to pay. The secret seemed to be to get a district with a thick population like those places to which Mr. Parsons had referred. With reference to the method of construction adopted in Sydney, it appeared that the road had been laid and relaid three times, and yet the result was not satisfactory, for the engineer of the Colony, in reporting to the Government, wrote, "The repairs and renewals have been very great, but the roads are now mostly in a fair working order. There is great difficulty in keeping the joints good, in consequence of the weakness of the fishing, which cannot be strengthened in consequence of the shallow depth of the rail. Also the creeping of the rails running the joints past the sleepers. This will, I am afraid, always be a source of annoyance and expense, unless a different rail with a continuous iron sleeper be adopted." It seemed rather formidable that in three years three systems of permanent way should have been put down, and that the engineer should be reporting that another was needed, when £19,404 per mile had already been expended upon the work. He had been told, by persons conversant with Sydney, that a great deal of public annoyance was occasioned by the tram-cars running through the streets, some of which were narrow, so that a person in a hansom cab hearing one of the engines approaching was apt to feel nervous. He made these remarks in no adverse spirit; engineers were always glad to obtain experience from the Colonies or elsewhere, because it was only by experience that they could be guided in their practice; but he was afraid that Sydney, however advanced, was not leading in a way that English engineers would like to follow.

Mr. Eppelsheimer.

Mr. W. EPPELSHEIMER observed that he had been connected with the cable system from its beginning, having in 1873 built the first successful cable-tramway in the world—the Clay Street Hill Tramway in San Francisco; and since then he had been identified with the system, making it in fact a speciality. He might also mention that he had acted as chief-engineer in connection with the construction of the Highgate Hill Cable Tramway. It was generally agreed that the cable system was an excellent one for tramways on steep gradients, but he ventured to say

Mr. Eppelsheimer. that it was equally good for level lines, as had been shown in Chicago, provided there was a frequent service of cars, either at regular intervals or at periods when a great augmentation of the carrying capacity was required. It must be borne in mind that a rope moving in a tube in a tramway track was a movable transmitter, which would carry the power to any point of the line, where the rope was running, and where the force might be required. Instead of any of the surplus power produced by the gravitation of the cars in going down hill being absorbed by the friction of the brakes, it would be received by the cable and transmitted to such section of the line where power was needed, thus relieving the engine. The extra effort required for the starting of a car would, by the help of this transmission, be taken from the common source of motion, and only in such quantity as was absolutely necessary. It would no doubt be observed that this was the only mechanical system by which such an equalization could take place, except, perhaps, electricity, which, however, was not purely mechanical, and could be used only under limited circumstances. Allusion had been made to the enormous cost incurred in the construction of cable-tramways in America, and he was well aware that this system more than any other gave opportunities to the engineer to expend injudiciously a very large amount of money; but he had also found that cable-tramways of proper lengths, say of 2 or more miles, and with a double track, would compare very favourably with lines of any other system when properly equipped for a five-minutes service. Moreover, a cable-line could provide a one-minute service without additional cost, except for cars. As an illustration of the cost, he would give a few figures relative to the lines that he had constructed. The Clay Street Hill Cable Tramway, constructed in 1873, was a double line 3,300 feet in length, and, with land, buildings, and rolling-stock consisting of six cars and six dummies, had cost £17,100, or about £13,800 per mile of single track. The Geary Street Cable Railroad, built in 1879–80, was a double track 13,100 feet in length, or 26,200 feet of single line. The rolling-stock consisted of twenty-six cars and twenty-six dummies, and, with land and buildings, the line had cost £60,000, or about £12,000 per mile of single line. Included in this £60,000 was a sum of £3,000 which had to be paid to two other tramway companies for the right of way over 3,000 feet of their lines, and now those companies drove horse-cars over the cable-track for the distance he had mentioned, the cars following each other about every five minutes. Besides having to join the tracks of the cable-road with those of the two other companies at the corners for the incoming cars, and at other corners for the outgoing cars, he had to cross three other horse-tramways and one cable-tramway, thus showing the adaptability of the system to crowded thoroughfares. The Highgate Hill Cable Tramway, which was the first of its kind in Europe, was constructed in a district where the Local Boards and the inhabitants were opposed to tramways. It was situated in three different parishes, and the local authorities had been very exacting. The line was only 3,780 feet long, and the track was double for 2,700 feet, the remaining 1,080 feet forming a single line, with two passing-places. The line proper, with the paving specified by Act of Parliament, and with five cars and three dummies, had cost, irrespective of land and buildings, £18,111. The engine-house had been very expensively constructed, owing to the requirements of the landlord, and, together with the lease, cost about £6,000. The engine-power was in excess of that at present wanted, in order to allow for a future extension of the line at the upper end. With regard to the wearing of the ropes and pulleys, which had been referred to as serious, his experience in the matter led him to the conclusion that the cost on that head would be about £180 per mile of rope per annum, which he did not think was a high figure, comparing it with the items of cost either in horse or steam-tramways, for additional wear and tear and sanding of the tracks. Mr. Eppelsheimer.

Mr. R. C. Rapier wished to say a few words respecting a system of tramway-engines that had been very successful on the Continent. It had been alluded to previously in a tone almost implying that it had only been tried as an experiment. He referred to the fireless engines of Mr. Francq, of Paris. These had been at work, more or less, for six or seven years, and at present there were twenty-one such engines in successful operation at Lille; and others employed at Marly, near Paris. They had been continuously in use for some years, and the general result was that, as compared with an engine carrying its own fire, there was an economy, under equal circumstances, of about 2½*d.* per mile. He had before him the particulars of the actual expenditure at Lille, as returned by the Company. The engines ran, on an average, 70 miles each per day, which was a good day's work for a tramway-engine, taking into account the number of times that it had to stop and start again. The mileage of each engine was nearly 20,000 per annum. The total number of kilometres run per day by all the engines was 852, and the Company was so well satisfied that they had already discontinued the use of engines Mr. Rapier.

Mr. Rapier. with fires, and next summer they proposed to extend the working of the fireless engine from 852 kilometres per day to 1,300 kilometres, an increase of 50 per cent. With such results the members would not be surprised to hear that the Academy of Sciences at Paris had awarded their Grand Prix Montyon to Mr. Francq for his improvements in tramway-engines. The condition of the prize was that it should be given to the most worthy inventor in the different useful instruments for the progress of agriculture, the arts, or sciences. The engines obtained their motive power from a large reservoir of hot water, at a very high temperature. That reservoir, when it contained 2 tons of hot water, was enough to serve for a distance of about 8 or 10 English miles. Of the engines at Lille, ten or twelve were in use at a time; and at the end of every trip their reservoirs were connected by a pipe with stationary boilers for the water to be re-heated. They arrived home with perhaps a pressure of 20 or 25 lbs. above the atmosphere, and were charged up to about 250 lbs., and then started again on the road. In the course of the journey they had to mount gradients of 1 in 20, and at Marly of 1 in 18, for a length of 3 furlongs. The system had not made more rapid progress because, to work the engine advantageously, the temperature of the water had to be raised very quickly, and that could only be done where there was a very large boiler-power at the depôt; and this could not be afforded unless there were a good many engines. With twenty engines in use, one would come in about every four minutes, and with two or three large boilers a small engine could be easily re-heated in two or two and a half minutes. But where there were only one or two engines the result was unfavourable, because there would be only one moderate-sized boiler at the depôt, and it would take, perhaps, a quarter of an hour to warm up each engine in turn. That was a tedious process, and on a small scale the system was not profitable. But the fireless engine, worked on a sufficient scale, was a very economical machine. It possessed all the advantages claimed for compressed air and electricity, by admitting the use of inferior coal in big boilers and getting a better evaporation, while with the hot-water engine there was no necessity for any steam-engine at home, nor for air-compressing pumps, nor for dynamos, all of which were troublesome to deal with in the hurry of tramway traffic. Then came the point where the fireless engine was apt to fail. If a small engine, built for an 8 miles journey, was required to run 20 miles, it would fail. But if everything was properly proportioned to the end in view, and to the local circumstances, there was no difficulty. The quantity of water to be carried was not excessive, having in view the duty to be done. The steam-boiler depôt should be as near the lowest level of the line as possible, and so placed that the latter end of the trip should be on the level or down hill, free from steep gradients. It was obvious that if an engine was required to surmount a gradient of 1 in 20 at the end of its trip, the conditions would not be so favourable as they would be if the engine mounted the gradient first and did the easy work last. Another advantage of the fireless engine was that it did not suffer so much from an imperfect permanent way as small sensitive locomotives. Every jolting caused by the permanent-way damaged the boiler. With the fireless engine the reservoir was simply a large and strong plain cylinder set upon two saddles mounted on the frame. Subjoined was a Table giving the working expenses for the month of November, 1884, on the Lille tramways; also another Table containing particulars of the same tramways. Mr. Rapier.

LILLE TRAMWAYS.

Expenses of Traction for the Month of November, 1884.

Francq's system.

Nature of Expense.	Amount.			Miles Run.	Per Mile.	Observations.
	£.	s.	d.		d.	
Wages: machinists, stokers, &c.	108	15	10	15,872	1·71	At Lille the cost of coal is 15*s.* per ton. Wages are very high. The gross cost of the fireless engine is 5·3*d.* per mile. At Rouen, St. Etienne, Lille, and Paris, traction by steam is worked under nearly the same conditions by ordinary tramway locomotives at a cost of 11·36*d.* to 16*d.* per mile. In Paris traction by horses costs 8*d.* to 10·56*d.* per mile per single omnibus. The cost of traction by fireless locomotives is therefore much less than the cost of any other system of working, whether by steam or by horses. The saving per day is at least £1 5*s.* per engine.
Fuel	98	15	0	15,872	1·55	
Other stores	13	2	6	15,872	0·207	
Maintenance	117	4	2	15,872	1·846	
Total cost per month	337	17	6	15,872		
Cost per train per mile	..			..	5·104	
Cost per carriage per mile	..			..	2·656	
Cost per ton per mile	..			..	0·2737	
Cost per seat per mile	..			..	0·064	

Mr. Rapier.

PARTICULARS of the TRAMWAYS at LILLE on which the "FRANCQ" FIRELESS ENGINES are at WORK.

Length of line	7 miles.
Length of track with Vignoles' rails	1·8 „
Length of track with Marsillon rails placed in the paving	5·2 „
Gauge	4 feet 8½ ins.
Curves Radius, minimum	65 „ 8 „
Radius, maximum	2,625 feet.
Maximum gradient	53 in 1,000.
Weight of train with locomotive	25 tons.
Speed per hour, maximum	12·5 miles.
Duration of the journey between Lille and Roubaix	50 minutes.
Weight of the engine, empty	7·3 tons.
„ „ „ in working order	9·8 „
Pressure, on leaving depôt	15 atmospheres.
„ at end of journey	5 „
Total train-mileage per annum (20 minutes interval between each journey)	276,600 miles.
Number of engines in service and in reserve	15
Approximate value of the engines	£12,500
Number of boilers in use and in reserve	6
Total heating surface of boilers	2,368 square feet.
Cost of boilers and fittings	£3,000
Average length of continuous service of engines without interruption for repairs	82 days.
Length of run between the limits of 15 and 3 atmospheres pressure, with two carriages and a total rise of 315 feet in the whole journey	14·2 miles.

Mr. Morris.

Mr. W. MORRIS (Westminster) desired to refer to a statement in Mr. Shellshear's Paper as to the engines from the Baldwin Locomotive Works being superior to those of English make. The cause of that would be found, as had been suggested by Mr. Kincaid, to be due more or less to the imperfection of the permanent-way; and it also arose in part from the manufacture of the engines themselves. When visiting America and engaged on Colonial railways he had found great prejudice against the adoption of English locomotives, being informed that they were not suited to a rough and uneven permanent-way. He consulted a locomotive manager who was working with English and American locomotives, and his statement was that the American engine was preferred because the various parts were not so accurately fitted as similar parts in the English engine, that there was more play between the working parts, and that they were therefore more suitable for a rough permanent-way. The English engine did not adapt itself to the unevenness of their roads. The American locomotives that he examined had light frames, and were altogether much lighter than those used in England. The manager further stated that in point of strength the English engines were far superior to the American, and that where an American locomotive would, in case of accident, be broken up, an English engine under similar conditions would be but little damaged. In 1882, when passing through San Francisco, he had the opportunity of carefully examining the working of the cable-system, the results of which he had submitted to the Institution.[1] He was much impressed with the way in which the system overcame such very steep gradients as 1 in 6, and also with the success which attended the brakes that were adopted to guard against accident. He had made a few calculations with regard to the working of tramways by this system as compared with steam. Taking the line referred to, he would assume, as Mr. Parsons had done, that there was a ten-minutes service; this would require twenty-five engines on a double line 8 miles in length. Twenty of the engines would have to be in constant work, the remaining five being spare engines in the shed. These twenty engines would probably require a staff of seventy men—drivers, stokers, cleaners, &c. On the cable-system, as compared with working by steam, there would be a saving in wages of sixty men, which, at 4*s.* a day, would amount to about £4,380 per annum. A saving in the cost of fuel, repairs and stores, would be 1½*d.* per car-mile as against 3·28*d.*, giving a further saving of £3,250. There was another item of saving on account of depreciation, which he had taken at ¾*d.* per car-mile, and that would amount to about £1,625. The total of the three items came to £9,255, to which must be added the £6,501 placed to dividend by Mr. Parsons; this would give a total net revenue of £15,756. The cost of the tramway mentioned was £6,600 per mile. It had been stated that £10,000 was a fair sum per mile for a cable-road, so that the total cost of 16 miles would be £160,000, the result of the increased revenue being a 9¾ per cent. dividend on the above amount, as against 6·6 per cent., or an increase of 50 per cent. in favour of the cable system of working, notwithstanding its extra cost. **Mr. Morris.**

Mr. ROBERT H. BURNETT said, as he had been in Sydney during the first three years of the use of tramways, and had been locomotive engineer of the Government railways in that colony, he desired to draw attention to one or two points relative to the Sydney tramways. In the first place, if the extra cost for **Mr. Burnett.**

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 210.

Mr. Burnett. maintaining the permanent-way for 1882, amounting to £14,000, referred to by a previous speaker, were added to the cost given in the Appendix, the result of the working in that year would be a little over 2 per cent. interest on the capital account, and the return for the whole of the four years of working —1879–80–81–82—would stand thus: that when in 1879 a length of 1½ mile was in operation, the working cost would be 51·59 per cent. on the earnings, and the rate of interest 33 per cent.; in 1880, with 4 miles open, the cost of working would be 70·83 per cent., and the interest on the capital 12·34 per cent.; in 1881 with 9½ miles open, the cost of working would be 83·31 per cent., and the interest 6·16 per cent.; and in 1882, with 22 miles open, the cost of working would be 93 per cent., and the interest 2·12 per cent., so that as the lines extended the returns gradually diminished—a result that was not at all satisfactory. The cost of the locomotive department of these tramways appeared to be very high, considering the work that was done. The average for three years was nearly 21*d.* per mile, while the cost of working the trains over the most expensive sections of the railways of the Colony for the same period was only 17¾*d.* As regarded the work done on the Sydney tramways—although it was a misnomer to call them "tramways" as they were essentially light railways—it was true that two cars, capable of carrying together one hundred and eighty passengers, were used on the trains running on some portions of the lines, and that they were crowded at certain hours of the day, and on holidays, yet the average number of passengers carried, even at the highest computation, was much below the capacity of even one car, as might readily be ascertained by multiplying the number of passengers annually carried by the distance over which they individually travelled (which Mr. Shellshear gave, as a maximum, at 2 miles), and then dividing the multiple by the number of train-miles run in the year. This, it would be found, gave the average number of passengers carried as forty-nine for the year 1880, forty-eight for 1881, and forty-five for 1882. Full particulars as to the number, steepness and length of the gradients were not given, and therefore it was not possible to determine exactly the amount of extra work which they involved. The steepest gradients, it was stated, were 1 in 18, and on one road there was a gradient of 1 in 23 "for a considerable length." It was also stated that on the heaviest section there was a ruling gradient of 1 in 20 for about a mile. These steep gradients, however, bore, he believed, a small proportion in point of length to the total

Mr. Burnett.

length of lines open; and though they doubtless limited, to a certain extent, the loads on the lines on which they occurred, they could not be taken as alone sufficiently accounting for the high cost of locomotion. One of the gradients of 1 in 18 was on the original line of tramway, and was little, if anything, more than ⅛ mile in length.

The traffic on the railways was, on the other hand, of a very heavy character. It necessitated the use of engines of the most powerful description, with cylinders 18 inches and 19 inches in diameter, by 24 inches and 26 inches length of stroke, with 11 to 12 tons per axle on the coupled wheels, the total weight of the engines with tenders in working order being from 55 to 60 tons. The main lines ascended the mountain ranges to a height of 2,500 and 3,500 feet respectively above the sea, with constantly recurring gradients of 1 in 40 and 1 in 50. On one main line there were gradients of 1 in 30 for 3 miles, and of 1 in 33 for 1½ mile. On the other main line there were inclines of 1 in 30 for a total length of nearly 2 miles, and of 1 in 33 for over 16 miles, with frequent curves of 8 chains radius for an aggregate length of 5 miles. There were also curves of from 8 to 12 chains radius for an aggregate length of 20 miles.

To enable a comparison to be instituted between the cost of working these undertakings in the Colony and in this country, it might be stated that the rate of wages in the former was from 80 to 100 per cent. higher, and the cost of materials used in repairs from 25 to 33 per cent. more than in this country, which, one thing with another, might fairly be taken as adding 66 per cent. to the cost of similar operations in this country. The converse of 66 per cent. on English cost was, of course, 40 per cent. off colonial cost. Therefore, to reduce the figures in the Table in the Appendix to the standard of this country, 40 per cent. should be deducted.

Next, as to the permanent-way expenses, it would be seen from the Table already referred to, that the average cost of maintaining the permanent-way per train-mile, taking the figures as there given, was 7·29*d.*, and, if corrected to include the whole of the expenditure in re-laying the lines in 1882, the average would be 8·95*d.* This was no inconsiderable amount for a "tramway," and was, in fact, more than the cost, per tram-mile, of maintaining for the same period the permanent-way of the suburban district of the main line of railway centering in Sydney, and which, with their far greater weight of trains and engines, amounted to only 7*d.*

Mr. Burnett. The popularity of the Sydney tramways with those who had occasion to use them, as affording an expeditious and pleasant means of transit, was unquestionable, and the energy with which the system had been developed and managed, and the success which, from some points of view, had attended their working, must be acknowledged. The circumstances which led to the introduction of steam-tramways in Sydney were, however, exceptional. The system was hurriedly introduced in the first instance, and, as the results showed, it had been extended faster than the later experience of its working warranted, either financially or from a mechanical point of view. Owing to the form of the rail, practically an ordinary "railway" rail with a movable guard, the absence of a proper and substantial road-formation contiguous to the rail, and the consequent difficulty experienced in maintaining the road-way at the requisite level, the ordinary road vehicles were greatly inconvenienced in using or in crossing the streets along which the tram-lines were laid; while, in consequence of the high speed at which the motors ordinarily ran, which ranged from 10 to 15 miles an hour (and he had often known it to exceed even the latter speed) all other traffic had practically to give way to them. If confined to the suburbs they might not be very objectionable, but running as they did into the heart of the city, they were a public nuisance to ordinary street traffic, and it might safely be asserted that in few equally civilized and populous cities would such a system of steam-railways be tolerated—certainly not within the outskirts of the town. One anomaly noticeable in these trains coursing the streets was, that while the whole of the railway lines, even in the most secluded parts of the country, were carefully fenced, the public, including the infirm and children, were left, even in the most crowded thoroughfares of the city, without the slightest protection of that kind.

It might, no doubt, be said that the system had been sanctioned by the legislature, the representatives of the popular will, and that that was sufficient justification for its having been adopted. Those who were conversant with public affairs knew, however, that in these colonies Acts of Parliament were not always obtained on their merits. It could readily be shown, by reference to public documents, that the Acts authorizing and providing the sum of £600,000 for the construction, not only of the 22 miles of tramway, referred to in Mr. Shellshear's Paper, as completed at the end of 1882, but of several other routes not then constructed, were passed early in 1880 under special pressure brought to bear on the Government of the day. This was done by large and influential deputations representing suburban interests, "including representatives," to use the words of the Commissioner of Railways in his report to the Minister, "of no less than twenty-two suburban municipalities," and also under the stimulus of the exceptional profits which the special traffic of the Sydney International Exhibition brought upon the original line, and which the official report on the working of the tramways, published up to the end of 1879, showed, in the absence of the heavy charges for repairs and renewals which had since arisen, to have yielded a return of interest on capital equal to 33 per cent.! The result was that the rights of the city were sacrificed to the interests of suburban municipalities. Mr. Burnett.

Further, if the railway terminus, as constructed twenty-five years ago, had not been inconveniently placed in the outskirts of the city, so as to render it impossible to properly and conveniently connect these suburban municipalities with the business portions of the city, these steam-tramways would never, he believed, have come into being; and notwithstanding their existence and all the advantages claimed for them, it had been decided, only a few weeks ago, to bring the railway terminus into the heart of the city, a distance of nearly 2 miles, at an expenditure of £450,000.

The heavy and increasing expenditure on the working and maintenance of the rolling-stock and permanent-way, and the consequent falling off in the rate of interest yielded, could hardly be regarded as a satisfactory result at the end of four years' experience of the Sydney steam-tramway system. Nor was it clear how the evil was to be met, for there appeared, by the report of the Select Committee of the Legislative Assembly—lately appointed to inquire into and report upon the purchase of rolling-stock and materials for the tramways, which had just been issued—that there was a great want of unanimity in the tramway department, as to the proper form of motor and vehicle necessary for the economical working of the traffic. By that report it transpired that the combined motors and cars, which Mr. Shellshear referred to as having been introduced from America, in the hope of greatly reducing the proportion of dead weight to paying load, had not proved satisfactory, and the abandonment of that system was therefore recommended by the Commission.

Mr. W. LYSTER HOLT said in 1878 he had made some remarks on tramway-engines before the Institution of Mechanical Engineers,[1] Mr. Holt.

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[1] Institution of Mechanical Engineers. Proceedings, 1878, p. 434.

Mr. Holt. and also before a Select Committee of the House of Commons,[1] and now with seven years' additional experience he had not changed his views much with regard to the motor that ought to be used on tramways. Hitherto only the manufacturers' and not the practical side of the question had been broached. With reference to the fireless engine, no doubt in some situations it would be suitable; but Mr. Rapier had not explained how he would prevent the visible escape of steam, which was contrary to the Board of Trade Regulations. As to the compressed-air system, the difficulty was, that if anything happened to the engines compressing the air the whole system would fail, and that would equally apply to the cable system. He agreed that for such gradients as 1 in 8 the cable system might be used, but in crowded cities like London, Manchester, and Birmingham, what would the public say if the cable failed for a single day? Their feelings would be very similar to those of the London public if the Metropolitan Railway were stopped for a like period. With reference to the Board of Trade Rules relating to tramway engines, he concurred with Mr. Parsons that as a whole they were a great safeguard to the public, but he thought, with the experience gained in working, that some of them might now be relaxed or modified, and others substituted of an equally stringent nature, with advantage to all concerned. Take, for example, the governor or speed-regulator, a delicate piece of machinery and very liable to get out of order; the Rules stipulated that this should be so constructed that it "cannot be tampered with by the driver," and it had been suggested that because these were in some cases boxed in that they complied with the Regulation; but as the mechanism was ultimately connected with the brake, he thought any driver could prevent their proper working, and it would only be according to all precedent that he would do so if, say, the governor applied the brake unnecessarily with the engine slipping badly on a stiff incline. His idea was that the automatic brakes should be done away with, and the personal responsibility of the driver increased. If the engine- and car-brakes proved insufficient, or failed to act on an emergency, he would make the cylinder-covers and movements strong enough to resist the strain, and would utilize the cylinders for obtaining extra brake-power. There was another stipulation, viz., that "arrangement shall be made enabling the driver to command the fullest possible view of the

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[1] Minutes of Evidence taken before Select Committee on Tramways (use of Mechanical Power) Bills, 1878, p. 33.

Mr. Holt.

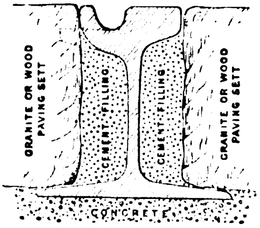
road before him," and this, though excellent in itself, might, in a few years, when the boilers became worn, be a source of danger; he alluded more particularly to those engines on which, to comply with this stipulation, the driver was compelled in one direction to be at the smoke-box end of the engine, and when consequently for half-an-hour or forty minutes at a time he never saw the fire-box. Mr. Parsons had spoken of Kitson's variable expansion-gear; but unfortunately drivers of tramway-engines seldom made use of the reversing lever except to reverse the engine, and he would recommend as an inducement that a quick-threaded screw should be used for actuating the expansion-gear and for reversing, as giving greater facilities and nicety of adjustment. Mr. Parsons was of opinion that a compound engine would not be an improvement, but referring to what Mr. Wilkinson had stated, Mr. Holt thought it was a very good system. If, for example, a driver was compelled, in consequence of a vehicle being in the way, to stop on a gradient of 1 in 12, and he could put live steam into a cylinder 16 inches in diameter, he could get over the difficulty of re-starting. As, in England, it was not permitted to show any steam, if by the compound system the steam could be emitted from the large cylinder, say at 6 lbs. above the atmosphere instead of 25 lbs., the difference in temperature of the steam would be nearly 40°, so that there would be this less amount of heat to get rid of in the condenser. There was another advantage also in the compound system. In the case of a line that was level, except for a small length where there was a gradient of, say, 1 in 12, instead of having a heavy engine to do the work, a lighter compound engine, with high-pressure steam admitted into the large cylinder on the gradient, would be sufficient. As far as his experience went, he had never known any engines or cars perform, for any length of time, the mileage suggested by Mr. Parsons, and it would be found in the return of the Board of Trade, that, taking all the cars on steam-tramways, their total mileage did not average more than 27 miles per car per day, while those worked by horse attained over 45 miles per day. Tramway engines did not average more than 33½ miles per day, and, on the authority of Mr. Price-Williams, locomotive-engines did not average more than 20,000 miles per annum. The reciprocating parts of a tramway engine having to work much more frequently than those of a locomotive in the same distance, it could hardly be expected to attain the same mileage for any length of time, and if a tram-engine could be made to perform an average of 10,000 miles a year, that, he thought, would be as much as could be

Mr. Holt. expected. He happened to know that the figures mentioned referred to the Birmingham and Aston Tramways. Now, in the first half year's report the repairs to the engines were quoted at 0·25*d.* per mile run, but in the next year, when the tramway had only been working eighteen months, they amounted to 0·80*d.* per mile. From his experience in Paris, working twenty engines by steam every day, he unhesitatingly said that after five years, tramway-engines would cost from 3*d.* to 4*d.* per mile, and tramway companies therefore ought not to allow a less depreciation than 20 per cent. per annum. The proper place for a speed-indicator, if anywhere, was in the car where the public could see it. An experienced driver knew well enough what was the speed; it was the public who ought to be informed upon that point, as a check on the driver. It would be easy to get a speed-indicator to act as a tell-tale. A tramway engine, in his opinion, ought to have large wheels, if only to lessen the wear and tear on the motion, and the cylinders should be large because, whether the engines had a link-motion or any other expansion gear, by having large cylinders (the size of the boiler need not be altered) they could then advantageously be worked expansively, and there would always be surplus power on a pinch. With regard to sand, his opinion was that if used at all, it should only be to check engines going down inclines. After an engine had passed over sand, the sand was ground into mud, which made it much worse for the engines that followed. On the tramways in Birmingham the rails were 103 lbs. per yard, being heavier than on many lines of railway. Engines to surmount steep gradients must have weight to give plenty of adhesion. Years ago it was a common thing for firemen on railways to be always sanding, but now, except in very slippery weather, they did not do so, because the weight of the locomotive had been increased in proportion to the heavier gradients and loads, and the same thing ought to be done with tramway-engines to work successfully and economically. A tramway-engine should always be run with the fire-box in front, and at every terminus the presence of a triangle, or some other means of allowing the engine and car to turn without uncoupling, should be compulsory. Not only would that be a great saving to the company, because many couplings were broken in shunting, but the driver would be in front of the engine, always near the fire-door and gauge-glass, ensuring more careful firing, and consequent diminution of smoke, whilst duplication of starting, reversing, and brake-gear would be unnecessary.

Mr. Winby.

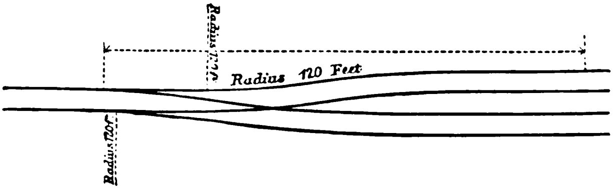
Mr. F. C. Winby observed that it was very difficult to make a comparison in the cost of working tramways, unless all the conditions were known. One line might be practically level, and another might have many steep and dangerous gradients throughout the whole length of the line. In the one case the cost might be 2*d.*, 3*d.* or 4*d.* per mile, and in the other three or four times as much. The same might be said with regard to the rate of working-expenses at a percentage of the receipts, and also with the maintenance of the permanent-way. Five years ago tramways were a nuisance to the ordinary vehicular traffic, in consequence of the construction of the permanent-way then adopted. The nuisance was not so much in the groove in the head of the tram-rail as in the exposure of the side of the rail to ordinary street traffic, consequent upon the paving setts next the rail being forced below the level of the rail. The rails then used were generally inverted channel iron or T iron, with a groove rolled in the head, and laid on chairs or longitudinal wooden sleepers, 4 inches in width. The strongest of these sections would scarcely support a load of more than 30 cwt. on bearings 1 yard apart, and was altogether unfitted to sustain the rolling-load of a locomotive engine of, say, 10 tons on four wheels. The annexed sketch (Fig. 9) represented not only a very strong rail, but a rail and sleeper in itself, which supported on the bottom flange the granite setts, thus making it practically impossible for them to be forced below the head, and thereby maintaining a level surface. A steel rail of this section, weighing 65 lbs. per yard, would bear 30 tons upon bearings 1 yard apart without appreciable deflection, and being laid upon a continuous bed of concrete, was capable of supporting the heaviest locomotive. It would be seen, by those who had a practical knowledge of the subject, that this section could not be produced by the ordinary mode of rolling rails, and the production was at one time considered impracticable. Hence the many combinations and modes of constructing tramways with the peculiar sections of rails in vogue, on account of the difficulty in rolling a groove in the head of a properly-constructed rail. Mr. Winby had overcome this difficulty by rolling the lip forming the groove parallel with the bottom flange, and then turning it up as it passed through the last groove of the finishing rolls.

Fig. 9.



Mr. Winby. With reference to points and crossings, the method shown in Fig. 4, p. 111, to acquire a straight lead through the points was wrong, as the engine and car coming from a double to a single line passed unnecessarily to the opposite side of the street, and contrary to the rule of the road. The principle upon which a straight lead through the points should be effected was shown in Fig. 10. It would be seen that this was made on the centre line of the roadway, and before diverging therefrom.

Fig. 10.



Now that all difficulties in constructing a permanent-way had been overcome, there should be none in providing a locomotive equal to the light work of tram-cars; but gradients steeper than 1 in 13 were a serious and dangerous element in working locomotive engines. He had seen, on a gradient of 1 in 13, an engine weighing 9 tons, with a car and freight weighing about 7 tons, with great difficulty keep in position, even with the use of plenty of sand. A car with all the wheels locked, under a slight impetus, would slip down a gradient of 1 in 10, which he considered the angle of repose. A pair of cylinders, with a large range of expansion, acting on an intermediate crank-shaft, placed well above and out of the dirt, and easy to be got at, connected by coupling-rods to wheels of large diameter, and bearing-surfaces of extra large dimensions, well protected, were the principal features to be considered in the design of tramway locomotive engines. He had also suggested the use of mechanical ventilation, to get rid of the heat from the atmospheric condensers, as he had found that one set of tubes acted as a jacket to the others. Simplicity of construction, strength of parts, and anything to obviate trifling repairs, should be the first thought in designing.

Hon. R. C. Parsons. The Hon. R. C. Parsons, in reply, said he proposed to deal *seriatim* with the remarks that had been made during the discussion. Mr. Edward Woods drew attention to the enormous cost of working the tramways in Sydney as compared with those mentioned in his Paper. He had looked carefully into the various items of cost of working tramways in Sydney. Only two engines had been supplied

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by Messrs. Kitson & Co., and the largest number had been furnished by the Baldwin Locomotive Works, of Philadelphia, U.S. As had been pointed out, the cost of 4½*d.*, which had been stated in his Paper as against nearly 39*d.*, showed a very great difference. The engines for light railways in Ireland, supplied by Messrs. Kitson and Co., had the same power as those sent to Sydney, and they were working on lines with very heavy gradients, and drawing loads comparable to those on the Sydney tramways. He had that day received a letter from Mr. John Barton, M. Inst. C.E., the engineer of one of the lines in Ireland, stating that the various expenses of those engines were:—wages, 2·3*d.*; oil, 0·35*d.*; coal, 1·8*d.*; repairs, 0·3*d.*, making a total of 4·75*d.* per mile. The expenses of the smaller engines mentioned in his Paper were 3·28*d.* per mile, showing that the large engines cost about 1½*d.* more than the smaller engines, and the total expenses of working the line were 1*s.* 2*d.* per mile. That was only about 2*d.* more than for the smaller engines, and did not amount to anything approaching the expenses in Sydney. Mr. Barton further stated that these engines were frequently driven at 12 miles per hour, and were admitted by all to run very smoothly. He thought the reason why the expenses on the lines in Sydney were so much greater than on the lines in this country might be accounted for, to a great extent, by the extreme roughness of the Sydney line, which was stated in Mr. Shellshear's Paper to have got out of repair several times, and the rails were so imperfectly fished that the joints became very defective, and the engines jolted tremendously. The first effect of engines jolting was that the springs gave way, and after that the various parts of the machinery got out of repair, so that the renewals became very heavy; but in Mr. Shellshear's Paper the items of expenditure were not mentioned, and it was difficult to go more fully into the cause of the excessive cost. He hoped that Mr. Shellshear would supply the Institution with some further information respecting the comparative cost of the working of the Sydney engines. Mr. Scott-Russell had pointed out what he considered to be a defect in Mr. Parsons' Paper, namely that it appeared to deal with a subject which was only in an experimental stage. He thought that the explanation of this misapprehension was very simple. The Paper was written entirely with a view of placing on record what he considered to be the best and most economical form of motive power for tramways. The great advantage of reading a Paper of that kind before the Institution was that it admitted of free discussion, and any one who had information to impart could put it

Hon. R. C. Parsons. forward; and thus there was a chance of arriving at a correct conclusion with regard to the best and most economical system. That was especially the case with regard to steam tramways, which dealt with a motive power that had been coming very much into use during the last few years. Mr. Scott-Russell also drew attention to the fact that the rails mentioned in the Paper were rather light. These rails were 92 lbs. per yard. Even on railways with engines weighing, say 40 tons, that was a heavy section, and he thought that if the rails were increased in weight beyond that it would be merely capital expended without any beneficial result. The joints were fished in the same way as on railways, and from the small wear and tear he thought that the joints had been as perfectly fished as possible. Mr. Scott-Russell next went into the question of HP. required to work the engines. It was difficult to follow his deductions in this matter, as he seemed to omit the question of time. First of all he assumed that 33,000 foot-pounds per minute was less than a HP. It was known that Watt made some careful experiments with regard to the strength of London horses. The London horses were above the average of the country horses, and Watt made out that 33,000 foot-pounds per minute continued for eight hours was the power of these horses. French HP. was below that, being 32,550 foot-pounds per minute, while the estimate made by Professor Rankine, who was one of the most careful experimenters, was below even that amount, and went down to 25,920 foot-pounds. He therefore thought Mr. Scott-Russell was mistaken when he said HP. should be assumed to be 65,000 foot-pounds. On tramways horses only worked a few hours in the day. A horse had done its work after a journey of from 10 to 12 miles, and on steep gradients the distance was sometimes much less. He thought that Watt was not very far out when he computed the strength of London horses at 33,000 foot-pounds per minute. Mr. Scott-Russell next stated that the power of taking a car along a road was 1 HP., and there and back 2 HP. That did not convey any idea to Mr. Parsons' mind. The time was neglected, and Mr. Scott-Russell's computation in that direction did not add much information. The wear and tear of tires on tramways was very great, especially on steep gradients. Mr. Scott-Russell estimated the life of a tire at from 21,000 to 22,000 miles, but a hard steel tire would last as much as 25,000, and he had even known it to last 30,000 miles without being worn out. He did not think there was any chance of arriving at a uniform gauge for tramways, which were generally constructed in towns. Unless

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they were laid to the railway gauge there was not much to be gained by uniformity. On the other hand in light railways, as in Ireland, great advantage was obtained by the uniformity of the gauge, namely 3 feet, which had been adopted. Mr. Graham Harris made some remarks with reference to compressed air. He stated that the friction on tramways was very great, even reaching 45 lbs. per ton. Mr. Parsons had never known it attain those figures. He thought that the engine must be very much out of gauge for the friction to reach 45 lbs. per ton, but he had known it as high as 30 lbs. in sticky weather, when the groove became full of mud, which was very incompressible. That was the time when friction reached a maximum. With respect to the combined engine and car he only mentioned that the best system was that introduced by Mr. Rowan, and which was also mentioned in Mr. Shellshear's Paper. Messrs. Kitson and Co. built the one alluded to by Mr. Shellshear, and sent it to Sydney; and he believed it had worked satisfactorily ever since. The chief advantage of a combined engine and car was that a lesser combined weight of engine and car would take a given load up a steep incline. Mr. Harris, he understood, had devoted a great deal of time to the question of compressed air, and he was sorry that the Institution had not been favoured with the results of the experiments, which he believed had been most exhaustive. Attention had, however, been drawn to the working expenses of the tramways at Nantes, as set forth in the Minutes of Proceedings.[1] By reference he found that the expenses of wages, fuel, oil, lubrication, maintenance and sundries amounted to 5·67 pence for one year, and 6·25 pence for another year. That was for an engine with cylinders 5¼ inches in diameter, and 10¼ inches length of stroke, cutting off at one-third of the stroke. That was a much smaller engine than the one described in his Paper, which had cylinders 8 inches in diameter and 12 inches length of stroke, and cut-off from seven-eighths down to three-eighths. That engine evidently would give out greater power than the one on the Nantes tramway; and from experiments he had made from time to time with compressed air, and from calculations of this form of power, he could not but think that although compressed air was preferable to steam, as it emitted no fumes or anything of that kind, the working expenses of compressed air would not at present compare favourably with those of steam. The economy would be much lower. Mr. Norman Selfe

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[1] Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 488.

Hon. R. C. Parsons. had made some remarks with regard to the Sydney tramways, and threw a good deal of light upon the question, but he only admitted that the lines were slightly out of repair. But that alone would not account for the immense amount of money spent from time to time on those lines. Mr. Selfe also mentioned the system of Mr. Pardy. It was an ingenious contrivance for taking in compressed air on an incline or along the road, and that was the only way in which he thought compressed air could be adopted with economy. It was worked at a low pressure, but he doubted whether a fresh charge of compressed air could be taken in so short a time as five seconds, which Mr. Selfe seemed to think possible. In this country the engine would have to wait more than five minutes to get a fresh charge. It was surprising how inefficient compressed air was when severe gradients had to be surmounted. The weight of the reservoirs was so great that the compressed air was soon exhausted, and a fresh charge had to be supplied. Mr. Cotton had directed attention to the question of no steam being allowed to go up the chimney of the tramway engine, and seemed to advocate the Merryweather engine. That was an engine he had had considerable experience of, and had seen it on various inclines, when steam was emitted freely from the chimney. Steam was allowed to go up the chimney, for the purpose of accelerating the draught and working with a lighter boiler. If no steam was allowed to go up the chimney, the boiler would have to be excessively large, and the engine proportionately heavy. A small amount of steam going up the chimney was generally not visible, except on a very cold, damp day; a very small amount of steam, if emitted, would be visible. The Board of Trade Regulations, as stated in his Paper, had been considerably modified during the last two years, and a small amount of steam at the present time was allowed to be emitted, unless it was proved to be a definite annoyance to the public. For the economical working of a tramway, this advantage, which had been wisely allowed by the Board of Trade, should be made use of, and the engines proportionately reduced in weight. Mr. Cotton mentioned that, on the Stockton and Darlington tramways, the working expenses were much lower than those he had quoted. Mr. Parsons had obtained the last report of those tramways, and he found that the working expenses were within 0·03*d.* of those mentioned in his Paper, or practically the same. Further on that line the receipts had been so low during the last year that even the Secretary had foregone £40 of his salary, showing that the working expenses must have been reduced to the very minimum. On that line also

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the cars were made to carry only from thirty to thirty-five passengers, while the cars on the line described in his Paper carried sixty passengers, and were generally fully loaded. The receipts on the Stockton and Darlington tramways showed that only six or seven passengers, on an average, were in the cars, and he thought that the working expenses on the Birmingham and Aston tramways, were far lower than on the Stockton and Darlington. Mr. Cotton also stated that, on the Dewsbury and Batley line, the working expenses were 2·57*d.* per mile. He had worked an engine on that line, and found his expenses there would, approximately, be the same as stated in his Paper, and as to reducing them down to 2·57*d.* per mile, he believed it was practically impossible. Mr. Joseph Kincaid next gave an account of the present position of the tramway question, and it was very fair in every way, except that it was stated that the engines described in his Paper had no water condensation. They had a water-tank, which absorbed a considerable amount of the steam which escaped uncondensed, and in very bad weather it was most useful. Mr. Pritchard drew attention to the question of a fifth-wheel, and the automatic brake being worked by means of it. Now the fifth-wheel actuated the brake without any connection with the wheels of the engine, and it had the advantage of not shutting off the steam when the driver allowed the engine to slip. In some ways, the automatic brake attached to the wheels was a safeguard against a careless driver allowing the wheels to slip round and round, and thus prevented the tires becoming worn out sooner than if no arrangement of this nature was attached. Mr. Crampton referred to the question of the oscillation of the engines, due to the outside cylinders being placed at an oblique angle to the line. He had made some experiments since the Paper was read, and he found, when the steam was admitted to the cylinders, there was no oscillation whatever. This effect could not be detected in any position of the crank, and he thought it could not produce any appreciable unsteadiness. The question of compound engines was a most important one, as economy of steam consumption was one of the first items to be considered, and Mr. Greig stated that the economy he had obtained from compound-engines as compared with simple ones amounted to from 25 to 30 per cent. Unfortunately the Royal Agricultural Society of England had not as yet undertaken trials of compound *versus* simple engines; but valuable experiments had been made in Germany with a view to ascertain what was the advantage of the former over the latter. Those experiments had been published

Hon. R. C. Parsons. in a German periodical,[1] and an abstract had appeared in the Minutes of Proceedings.[2] The two engines that had been compared were, one a simple engine constructed by Wolf of Buckau, and the other manufactured by Messrs. Ruston, Proctor and Co. The result was that the gain in economy of the compound-engine amounted to 10 per cent. That was a very small advantage for a compound-engine, and he thought the extra complication which was introduced into a compound-engine as against a simple engine was greater than the resulting economy was worth. Mr. Lewis had given some valuable information with regard to the question mentioned in Mr. Shellshear's Paper of doing without a condenser, and allowing an engine to puff through the streets. It appeared that forty-eight persons had been injured and several killed in the streets of Sydney during the year, and this showed that the Board of Trade Regulations were necessary to protect the public from injury. Mr. Rapier mentioned that the economy of the hot-water engine over steam was 2½*d.* per mile. If that was subtracted from the working expenses, as shown in his Paper, there would remain only ¾*d.* per mile to pay the driver, and nothing for any other expenses, and it would be very difficult to find a driver for ¾*d.* per mile. A hot-water engine therefore could hardly be worked at as cheap a rate as Mr. Rapier had stated. Mr. Holt considered it would be a great advantage to reduce the number of parts in a tramway-engine, and make it more simple. He thought the Board of Trade had very wisely imposed the various restrictions. They were for the benefit of the public, and though Mr. Holt seemed to object to the automatic brake, he regarded it as a protection to have one on an engine.

Correspondence.

Mr. Aspinall. Mr. J. A. F. ASPINALL remarked that a short branch of light railway was being worked by the Great Southern and Western Railway Company of Ireland. The branch in question left the Kerry branch of that railway at Gorbaltea, and ran to Castle Island, a distance of 4½ miles. It was laid to the standard Irish gauge of 5 feet 3 inches. It had been constructed under the "Regulation of Railways Act, 1868," 31 & 32 Vict., c. 119, which in clause 28 enacted that:—(1.) "The weight of locomotive-engine, carriages,

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[1] "Der Civilingenieur," 1884, p. 237.

[2] Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 507.

Mr. Aspinall.

and vehicles to be used on such railways shall not exceed a greater weight than 8 tons to be brought upon the rails by any one pair of wheels;" and (2.) "The speed of trains running on such railways shall not exceed at any time 25 miles per hour." The gradients were not severe, short lengths of 1 in 122, and 1 in 193 being the steepest on the line. The engine, which was made expressly for it, was an ordinary six-wheeled coupled tank-engine, having wheels 3 feet 8 inches in diameter. The cylinders were 10 inches in diameter by 18 inches length of stroke. The heating surface of the fire-box was 52 square feet, and of the tubes 310 square feet; total, 362 square feet. The engine-frames ran through in the rear, and a carriage of two compartments was carried on a four-wheeled bogie. The weight on the leading wheels was 6 tons 2 cwt.; driving-wheels, 6 tons 14 cwt.; trailing-wheels, 6 tons 14 cwt. The total weight of the engine was 19 tons 10 cwt., and of the four-wheel bogie carriage, 7 tons 4 cwt.

He appended particulars of the cost of maintenance, coal consumed, and work done in the nine years since 1875, when the engine commenced work. In that period it had been thoroughly repaired in the shops three times, and was now in good working order. The ordinary carriage and wagon rolling-stock of the Company was hauled over the line. The economical working, as far as the locomotive expenses were concerned, was due, he thought, to the simple form of engine employed, and to ample bearing-surfaces, which enabled it to compare favourably with the lighter construction of many tramway engines. The bogie-carriage would probably not be required on any other light railway, but only the simple coupled locomotive.

LOCOMOTIVE EXPENSES.

Castle Island Engine for nine years ending June, 1884.

		£
Original capital cost of locomotive engine and bogie-carriage		1,584
Miles run		163,742
	Pence per mile.	Pence per mile.
Superintendence	..	0·302
Running expenses, wages	2·199	..
,, ,, coal	1·218	..
,, ,, water	0·214	..
,, ,, stores	0·316	..
		3·947
Repairs		0·749
Total locomotive expenses		4·998
		Tons.
Average load 3½ vehicles =		35
		Lbs.
Consumption of South Wales coal per mile		14·21

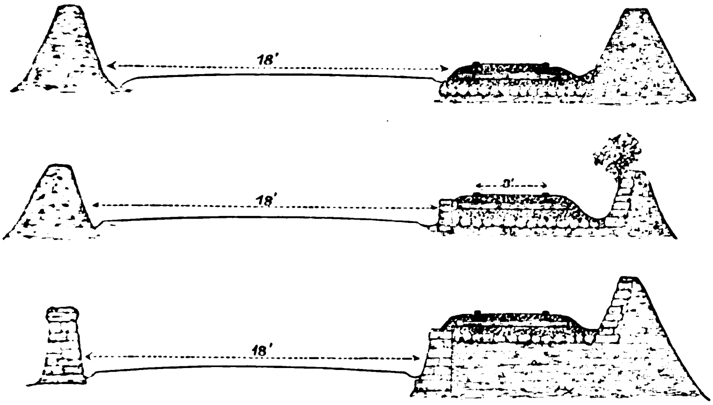
Mr. Barton. Mr. J. G. BARTON observed that, in view of the large number of steam-tramways likely to be constructed in Ireland during the next few years, he considered a short account of the Castlederg and Victoria Bridge Steam-Tramway, which was the first constructed in Ireland for both passenger and goods traffic, might be of interest. The tramway connected the town of Castlederg, Tyrone, with the Great Northern Railway of Ireland at Victoria Bridge Station. The length of the line was 7 miles. Except at the termini it was laid throughout along one side of the public road, this road having an average width of 25 feet. A breadth of 18 feet of roadway was left everywhere between the tramway and the opposite fence, and where there was a footpath between the tramway and the kerbstone of the footpath, which was always on the opposite side of the road. From Victoria Bridge Station the road rose in the first 2 miles 215 feet to the summit, the gradient for a great part of this distance being 1 in 30, which was the steepest on the line; the longest continuous gradient of this rate of inclination was 400 yards. After passing the summit the line fell for some 80 feet in the next $\frac{3}{4}$ mile. From this into the town of Castlederg the gradients were fairly good. With the exception of a short curve of 120-feet radius leading into the passenger station at Victoria Bridge, there was no curve on the line of less than 300-feet radius, but there were some of this radius on the steepest gradients. Very little land had been taken except at the termini and passing places, the whole amount being about 5 acres. The gauge of the tramway was 3 feet. The permanent-way consisted of a 45-lbs. steel flange rail of the ordinary railway type, laid on cross-sleepers 2 feet 6 inches apart from centre to centre, except at the joints, where they were only 2 feet apart. These sleepers were of creosoted Baltic timber, 6 feet long by 8 inches by 4 inches, machine-grooved to take the rails; and, as on the curves, the outer rail was given the proper elevation, the rails were set with the usual cant. One result of this was, that there had been no case of a train leaving the road on any of the curves. The rails, which as a rule were 27 feet long, were secured to the cross-sleepers by six $\frac{5}{8}$-inch fang-bolts, two at each end and two in the centre, and to each of the remaining sleepers they were secured by two square $\frac{5}{8}$-inch jagged spikes. The rails were fished together by the ordinary plate-fishes, secured by four of Ibbotson's steel bolts and die-nuts. The superstructure of the tramway was thus formed:—For a width of 4 feet on each side of the centre line the road was brought to a level generally 1 foot below the surface. As, how-

Mr. Barton.

ever, the tramway gradients never exceeded 1 in 30, and as the way did not follow all the short dips and rises in the road, the formation-level varied from about 3 feet below the road surface to 2 feet above it. It not being considered advisable to have the tramway-rail level below the road, in those cases where this rail-level would have been below the surface the whole of the road was cut away to the level of the rail.

The line was hand-pitched 6 inches deep for the full width of 8 feet, and from this to the bottom of the sleepers there was a layer of 4 inches of ballast. The ballast was brought up to within 2 inches of the level of the top of the rail. Whenever the rail was more than 6 inches above the road-surface, and less than 1 foot, a stone kerbing was laid along outside the end of the sleepers between the tramway and the road, and when the top of the rail exceeded 1 foot in height over the road, a dry stone retaining-wall was built between it and the road. A water-table was cut along the road-side of the tramway, and when necessary on the opposite side, from which outlets were made to carry off the water. The cross-sections of the public road and tramway (Figs. 11) showed the three positions described.

Figs. 11.



Wherever roads were crossed, guards of oak or elm were bolted to the sleepers 2 inches from the rail, and the crossing was raised to the level of the top of the rail with metalling. The tramway was single throughout with the exception of three passing-places or sidings. These were about 2 miles apart. At each end of the tramway the line entered a fenced-off station-yard. That at

Mr. Barton. Castlederg was similar in most respects to an ordinary small railway station. It contained a passenger-station house with waiting-room, offices, &c.; a goods store, engine and carriage sheds, cattle platform, &c. The offices of the company were attached to the passenger-station house. These buildings were all of a substantial and permanent character. At Victoria Bridge the passenger cars ran alongside the back of the Great Northern Railway passenger platform, whilst the goods and cattle were brought to a transhipment platform. This platform and the lines at each side of it were covered. The platform was 120 feet long and 12 feet wide. The levels of the broad-gauge (Great Northern Railway) and the narrow-gauge (Castlederg Tramway) lines at each side were arranged so that the floors of the wagons were at the same level as the platform. With the exception of coal, timber, and slates (which were imports), all the goods and the cattle were transhipped across this platform almost entirely by ordinary hand-trucks, which were wheeled from one wagon across the platform to the opposite one. In the case of coal, slates, and timber, the two sets of wagons were brought close together so that the sides almost touched. The broad-gauge line was laid at a higher level so that the wagon floor was above the side of the smaller trucks. To transfer the coal a light iron shoot was hooked on to the larger wagon, the side-door was opened, the coal fell to the bottom of it, and through this the coal was shovelled into the smaller wagon. Slates and timber were lifted from one wagon to the other. The transhipment of the cattle at the platform was effected by a gangway running transversely on small wheels, which was brought opposite the doors of the two wagons from and to which the cattle were to be transferred. The doors being then opened they were easily driven across from one wagon to the other. The cost of the transhipping of the goods did not exceed 4*d.* per ton.

The rolling-stock was a subject to which much attention was devoted and with most satisfactory results. It consisted of two engines supplied by Messrs. Kitson and Co. Their weight, with coal and water, was nearly 14 tons each. They were on two pairs of coupled-wheels 2 feet 6 inches in diameter, the wheel-base being 6 feet 6 inches. The cylinders, which were outside the frames, were 12 inches in diameter, and the length of stroke was 15 inches. The safety-valves were set to blow off at 160 lbs. pressure per square inch, and the working-pressure varied from 100 lbs. to this amount. In specifying for these engines Mr. Barton required that they should (in addition to themselves) take a load of 50 tons up a gradient of 1 in 30 at a speed of at **Mr. Barton.** least 4 miles per hour, on a wet day. This they had successfully accomplished, and on three or four trials they had taken loads of over 50 tons from Victoria Bridge to Castlederg. The engines were fitted with both hand-brakes and powerful steam-brakes, which were able to pull up the train of 50 tons in a distance of 70 to 80 yards on a descending gradient of 1 in 30, the speed being 8 miles per hour. Centre buffers were used. The couplings were automatic; they consisted of a horizontal link fastened into a slot in the centre of the buffer. When this met that to which it was to be attached, the link passed into the second buffer and raised a pin, which, when the link went home, dropped again into the link. Side-chains were also attached to each vehicle. There were four passenger cars, three composite first and second class, and one wholly second class. These cars were much stronger than the ordinary street tramcars, the underframing being of rolled-iron beams. They were 23 feet long from buffer to buffer, and were on four wheels 7 feet 6 inches apart from centre to centre. The wheels were 2 feet 6 inches in diameter. The cars accommodated twenty-two to twenty-four passengers each, the entrances being at the ends. The first-class compartments were fitted up similarly to an ordinary first-class railway carriage, the seats, however, running longitudinally. There were no seats on the roof. These cars weighed 5 tons each when empty. There were twenty wagons in all, fourteen covered and six open, 13 feet long inside and 6 feet wide, carrying 5 tons. They were on two pairs of wheels, 2 feet 6 inches in diameter, the wheel base being 7 feet, and they weighed 3¼ tons and 2¾ tons each respectively. There were also two vans weighing over 5 tons each, fitted with powerful hand-brakes.

It was intended to fit all the carriages and the vans with continuous automatic-brakes, controllable by either the engine-driver or the guard. The Parker-Smith, a continuous, automatic, mechanical brake, had been adopted for some of the vehicles, but up to the present this had not proved quite successful. There were three stations between Victoria Bridge and Castlederg, and the trains only stopped at these places. This arrangement, which was found to work very satisfactorily, was necessary, as a punctual train service was required in order to catch the Great Northern trains at Victoria Bridge Station. The speed was limited to 12 miles per hour, forty minutes being the time allowed for the journey. The total cost of the tramway had been £21,000, or £3,000 per mile, made up thus:—

Mr. Barton.

	£.
Cost of Act of Parliament	1,000
Land	500
Permanent-way materials	6,000
Contract for construction of line	4,800
Stations and passing places	2,000
Rolling stock	5,300
Engineering, law, and management	1,400
Total	21,000

The works were commenced in October 1883, and the tramway was opened for public traffic by the Marquis of Hamilton on the 10th of July, 1884, and since then had been doing a fair goods and passenger traffic. The working expenses for the half year ending the 31st of December, 1884, amounted to £550, or 75 per cent. of the gross receipts; but this percentage would be reduced as the traffic improved, as a much larger traffic could be handled with the present staff. The number of miles run in the half year was 9,464. The working expenses were therefore 1*s.* 2*d.* per mile run. Of this, 4¾*d.* was the cost of the engines, made up thus: wages, 2·30*d.*; oil, waste, &c., 0·35*d.*; coal, 1·80*d.*; repairs, 0·30*d.*; total, 4·75*d.* The tonnage in the half year was 2,576; the number of passengers was 15,966. A tramway like this afforded facilities for opening up rural districts where the traffic was not sufficient to warrant the large expenditure that a railway would entail. It supplied a want which had been much felt in Ireland, and the Tramways (Ireland) Act of 1883 showed that the Government had recognised this fact. By saving the cost of land, fencing, signal-arrangements, besides to a large degree excavation and culverts, these tramways could be constructed on suitable roads at a little more than half the cost of narrow-gauge light railways. The speed having been now raised to 12 miles per hour, removed to a great extent a serious objection as regarded the passenger traffic.

Mr. Bramall. Mr. H. Bramall considered that where tramways were free from heavy gradients, and the ordinary cars could be worked by one pair of horses without unduly distressing them, horse-traction would compare favourably with any mechanical traction yet brought forward; and where the route was circuitous, through not too wide streets, crowded with traffic, other than merely economical considerations would sometimes operate to decide the question in favour of horse-traction. When, however, steep gradients had to be overcome, and in suburban and rural districts, mechanical traction would ultimately supersede that by horses; and there was no

Mr. Bramall.

system of mechanical traction which presented so many advantages of economy, adaptability, and efficiency as that by steam. He did not agree that the best type of engine was one acting directly upon the cranks of the driving axle. The road surface being traversed by vehicles of all kinds, was in a state of constant mud or dust, and this getting into the bearings and working parts, caused an excessive amount of wear and tear, which probably reached its maximum where the cylinders were placed low. The unavoidable irregularities in the rails, and rapid and unequal wear of the tires, added to the difficulty of keeping the machinery in proper adjustment. The limit of speed fixed by the Board of Trade, with the small driving-wheels and low piston-speed necessary where direct-acting engines were used, would seem to suggest, and almost invite, the use of "geared" engines, since by their adoption the diameter of the driving-wheels could be increased, as well as a fair rate of piston-speed be obtained, and all the working parts of the engines could be kept effectually out of reach of mud and dirt.

With respect to the latest or "worm-geared" type of Wilkinson engine, the strain on the crank-shaft being in a longitudinal, or, so to speak, "fore and aft" direction, the wear of the bearings would have a tendency to result in throwing the cranks out of centre with the cylinders; but this was counteracted by the use of a thrust-bearing similar to that on a screw-propeller shaft, but made in two equal pieces adjustable in either direction by means of wedges. The arrangement of the Wilkinson boiler with "Field" tubes gave a remarkable amount of steaming power for the small space occupied, with the least disturbance of water-level in passing over steep gradients, while its evaporative efficiency reached 9·7 lbs. of water per 1 lb. of coke. The temperature of the feed-water was 62° Fahrenheit, and the steam blew off at 50 lbs. pressure.

Mr. Browne.

Mr. B. C. Browne, in respect to the allusion by Mr. Parsons as to the possibility of the brake of the engine being put on accidentally when the wheels slipped, said that as he understood the engine, if the wheels were to slip in going up a steep incline, the brakes would be put on and the steam would be shut off. Now it was known to be easier to keep an engine going than it was to start it again if it stopped. Would not an engine, therefore, under these circumstances, with a heavy car behind it, be in an awkward situation, and how was this got over in actual practice?

Mr. Churchward.

Mr. W. P. Churchward observed that the financial success of a tramway company depended, in the first instance, upon the engineering skill and economy displayed in the construction and

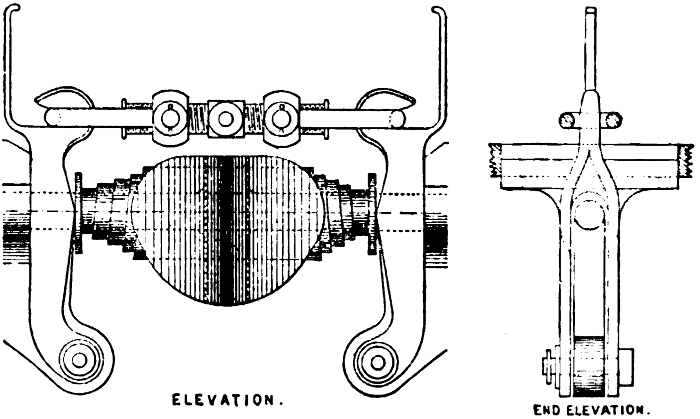
Mr. Churchward. working of its line or lines, and secondly upon local results regarding the nature and amount of its traffic. Failure was more often caused by an extravagant outlay of capital in the original construction of a line than by the poorness of the traffic; hence it was of primary importance that due economy should be studied, and exaggerated ideas as to receipts be suppressed. As a rule, however, economy was thought of too late. It might be useful to compare the construction and mode of working steam tramways in the North of Italy with those described by the Authors of the Papers. The system of permanent-way generally adopted was that of cross-sleepers, with the Vignoles rail and a separate guard-rail. The guard-rail, in form like the half-section of a Vignoles rail, was used only where the line was liable to be crossed by ordinary carts, through towns and at road-crossings, or around sharp curves. The space between the guard-rails was usually paved with pebbles. The sleepers, of oak wood, 7 feet 6 inches by 6¼ inches by 4¼ inches, were laid on ballast of ordinary gravel or shingle. The gauge of the lines in general was 4 feet 8½ inches. The lines were invariably laid on one side of the road, and crossed it only where absolutely necessary. The rail next the road was kept even with it, so as to allow of the free drainage of the road, and small gutters were made, about 30 feet apart, between the sleepers and underneath the outer rail, to allow the drainage to be carried into the main gutter. A width of at least 2 feet existed between the outer rail and the road embankment or gutter, as the case might be. The line was usually fenced off from the road by boundary stones of granite, 1 foot in diameter and about 2 feet 8 inches above the ground, placed 15 feet apart, there being a clearance of about 18 inches between the rail and the wall. Thus the width of road occupied by the line amounted to 8 feet 6 inches in all with the rails. In many instances, where the line passed through the villages, very little distance was left between the rails and the walls of the houses, so that it was dangerous for passengers to extend their heads or arms from the carriages, but few or no accidents had occurred, as the risk was well known. The points and crossings were made as on railways, and were protected by the guard-rail. The switch-rod passed into a strong iron box, where it was attached to a lever, which lever was worked by a removable handle. The box was flush with the ground, and placed in a suitable position close to the rails. The cost of permanent-way laid in the manner described, with a steel rail weighing 40 lbs. to the yard, was, for an ordinary single line, approximately 15*s.* per lineal yard; with guard-rail on one side

Mr. Churchward.

only, as used around curves, £1 0*s.* 4*d.* The guard-rail weighed 26 lbs. per lineal yard. A single line of rail, with guard-rail on each side, and pebble-paved between and 18 inches outside the rails, came to £1 8*s.* per lineal yard. The fitting of points and crossings, for formation of a double line or sidings, amounted to £2 4*s.* per yard. The average cost of a fully-equipped line was about £3,000 per mile. The requirements and regulations regarding the use of steam were not so severe as those of the Board of Trade in England. Horses and animals soon got accustomed to the slight noise and steam of the locomotives. The regulation speed was 12 miles an hour on the high road, and 4 miles within the towns. Trains might be composed of four carriages, occupying a total length of nearly 100 feet, including the engine, for the passenger traffic, and six wagons, 132 feet length, for the goods traffic. In the latter case the speed was reduced from 12 miles to 8 miles an hour. Engines of the weight of 12 tons might be used, and a net load of 30 tons of goods be drawn in one train, the average load of each wagon being 5 tons. Many types of locomotives were adopted on the various lines. The favourite was that made by Messrs. Henschel and Sohn, of Cassel, which in design resembled the English Merryweather engine. It was neatly proportioned, and its motion was well protected. A small 8-ton engine of this type was capable of drawing six loaded wagons, or a gross weight of nearly 40 tons, on an ordinary line with curves of 1½-chain radius, and gradients of 1 in 30, at a speed of 10 miles an hour, with a consumption of 10 lbs. of coal per mile. A careful analysis of the working of fifteen engines of this type, running nearly 14,000 miles per engine during the year 1883, gave the cost of traction, including repairs and maintenance, at 5½*d.* per mile, the cost of coals being 32*s.* 6*d.* per ton. The carriages were of light construction, about 20 feet in length, with a platform at each end, and gates on each side of the platform, from which there was access to the seated portion of the car. They contained sixteen places within, and room for eight passengers standing on each of the platforms. Of late, carriages of a larger type, to contain between fifty and sixty passengers, had been introduced on some of the lines. A gateway in the centre of the platform enabled the conductor to pass freely from one carriage to another. A simple and effective coupling, known as the Grondona coupling (Figs. 12 and Fig. 13, p. 194), was extensively used. It consisted of a buffer-plate welded in one with the draw-bar, which passed through a casting fitted in the centre line underneath the platform of the carriage. A drag-hook was

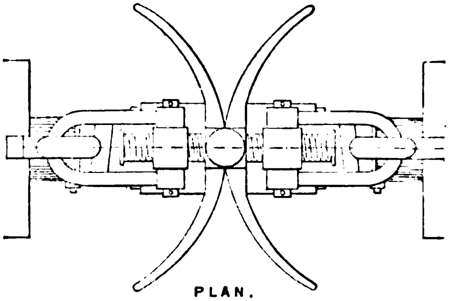
Mr. Churchward. attached to the casting, and acted upon a spiral spring fitted between the buffer-plate and the casting. The buffer-plate was nearly 2 feet long; it was oval at the ends, curved to a radius of 12 inches, and was 8 inches in depth. The coupling-link was attached above the plate to the drag-hook of each carriage, and could be shortened by the screw-bolt. Safety-chains were also attached on each side. The cost of repairs and maintenance of the carriages and wagons was slight, and compared favourably with the charge of 0·41*d.* given in Mr. Parsons' Table.

FIGS. 12.



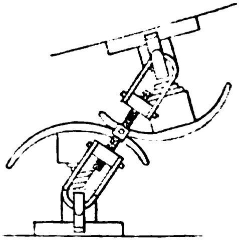
ELEVATION.

END ELEVATION.



PLAN.

FIG. 13.



GRONDONA COUPLING.

Mr. Gordon. Mr. ROBERT GORDON had been enabled, through the kindness of Signor Giuseppe Bianchi, President of the College of Engineers and Architects of Milan, to obtain the following information respecting the steam-tramways of the province of Milan.[1] The

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[1] Published in a work called "L'Impianto e l'esercizio dei Tramways nella Provincia di Milano." ("The construction and operation of the tramways in the Province of Milan.")

Mr. Gordon.

total length of tramway worked by steam in that province was, at the end of 1881, about 193 miles; 140 miles additional were projected, or in course of construction. The city of Milan contained about 300,000 inhabitants. With Milan as a centre the various lines radiated in all directions through very rich agricultural districts, and reached all the more important towns of the province. In many cases they were parallel to the principal railways; but they served a traffic differing essentially from that of the railways, where the trains ran at fixed times on a few occasions daily, but at high rates of speed between termini of importance; while on the tramways, which for the most part followed the provincial or commercial highways, the trains ran generally at intervals of one hour or two hours, stopping very frequently, and with maximum speeds of 9 to 11 miles per hour in the open country, but considerably reduced in towns or near dwellings. By using the highways the cost of construction had been kept as low as possible; but in some few cases new portions of line had to be made, and in others the roads had been widened, and some large bridges had been strengthened. As a rule the rails were carried on the side of the road, and a totally separate way was kept for the line by stone walls or piers; but on the narrower roads the tramway followed the centre, and shared it with the ordinary traffic. Where possible a width of from 10 to 12 feet was reserved for the tramway, which was always well ballasted and drained, the ballast being on an average 10 feet wide by 14 inches deep. In almost every case ordinary railway rails, mostly of the Vignoles type, were used. These varied in weight on the different lines, but averaged from 40 to 50 lbs. per yard; while on the Monza-Barzano line the rails were double-headed about 70 lbs. per yard. All the lines were on the 4 feet 8½ inches gauge. Transverse sleepers were generally used about 8 feet long by 6 inches by 4 inches, placed 3 feet apart from centre to centre. When passing through towns or round sharp curves a counter-rail was placed on the inside of each rail, from 1¼ inch to 1½ inch apart from it. Generally the ordinary rail was doubled; but on the Milano-Pavia line a shallow channel-iron was used for the counter rail.

The tramway mostly followed the road, both in its vertical and horizontal alignment. As a rule the gradients in the plain country were not severe; but on the mountain ways of the Saronno-Como and Monza-Barzano lines, inclines as steep as 35, 37, 45, and 53 per 1,000 existed, and were regularly worked. The last-mentioned line had a difference of level of 222 metres in

Mr. Gordon. a total length of 19,561 metres. Curves of 18- to 25-metres radius were permitted in towns; but the minimum curve allowed in the open country was 50 metres. Trains made up of a locomotive and four carriages, one of which might be for goods or baggage (always to be next the engine), not exceeding 100 feet in total length, were run on the tramways. Separate accommodation was provided for first- and for second-class passengers; the rates varying from about ¾*d.* to 1*d.* per mile for the former, and ½*d.* to ¾*d.* for the latter. Various types of carriages were used; but all were on the American plan of a central passage-way. The number of passengers carried in each varied from forty to sixty; the dead weight of each carriage ranged from about 2 tons to 3 tons. The total weight of train allowed by law varied from two and a half times the weight of the locomotive in the plain country, to one and a half time in the mountains. The engines on the different lines were of several types. The conditions required to be fulfilled by them were the following:—1. That they shall offer no danger to the passengers or dwellers near the lines. 2. To cause no noise or smoke. 3. The mechanism and the fire to be concealed. 4. To emit no odours, nor discharge cinders, or coal, or water, &c., on the roadways. 5. The working parts to be protected from dust and mud. 6. To be able to pass round curves of 20-metres radius with ease. 7. To be furnished with efficient and easily-managed brakes, capable of bringing up a train, moving at the rate of 12 miles an hour down an incline of 2 to 3 per 100, in a space of 20 metres. 8. To be capable of easy replacement on the rails if run off. 9. To be able to run in either direction without being turned. The principal types of engines adopted were those of Brown, of Winterthur; Krauss, of Munich; Henschel, of Cassel; the Belgian Society, and Cerimedo, of Milan. The first mentioned had a vertical as well as a horizontal barrel for the boiler, thus securing dry steam, but restricting the water evaporating surface, as the horizontal part was always kept full. Two outside horizontal cylinders were placed 2 feet 4 inches above the axles of the wheels, the motion being transmitted from the piston-rods to the cranks by a balance-lever, which also moved the distributing-valves directly without eccentrics. The whole arrangement was complicated, and required more parts than the ordinary method, while it was susceptible to the slightest shocks to the engine on the roadway. The vertical boiler interfered with the view of the driver when moving in the one direction. Two sizes of engines were used, each on four coupled-wheels, weighing respectively 14,553 lbs. and 19,625 lbs. in working order. The

Mr. Gordon.

Krauss engine was one of the best machines made in Germany. It resembled an ordinary locomotive with its horizontal tubular-boiler and two outside horizontal cylinders. The whole of the controlling apparatus was grouped near the fireman, and near an Exner brake, permitting complete surveillance over the train and the road in both directions. The machinery was well protected from dust. A peculiarity of this engine was the water-tank in the framework of the machine, capable of carrying from 1 ton to 2 tons, or sufficient for a journey of 35 miles, with the weight low down. Seven sizes of this engine were constructed, some with six wheels. Three sizes were used on these tramways of 30, 45, and 60 HP., weighing in working order 19,000 lbs., 21,000 lbs., and 27,500 lbs. respectively. The Henschell engine had two inside cylinders and two coupled axles. The boilers were horizontal and tubular, with a steam dome. The cylinders were inclined to the axles. The inside cylinders were found objectionable, as the machinery was more liable to injury from sand and mud on the road, and the crank-shaft was heavy and costly, while the boiler had to be raised high. The weights of the two sizes of engines used were 16,000 lbs. and 20,000 lbs. respectively in working order. The Belgian Society made its engines in Italy. The boilers were horizontal and tubular, but with a vertical steam-chamber near the chimney. The same remark applied to this as to the Brown engine. The mechanism was outside and completely protected. Its brake power was weak and inefficient. It had six wheels, four of which were coupled. Its weight in working order was 18,147 lbs. The Cerimedo engine had four coupled wheels, with, in some cases, outside cylinders, and in others inside ones. The boiler was horizontal and tubular, with a steam-dome at one-third of its length. Its mechanism was protected from dust and exposure, and the discharge of waste steam was silent. Four sizes of this engine, which had proved most serviceable, were in use, of 30, 40, 50, and 60 HP., weighing respectively 13,250 lbs., 17,640 lbs., 22,050 lbs., and 26,460 lbs. when in working order.

The lines in operation in 1881 were owned by five companies, whose names, with the termini of the lines and the dates of concession, were given in the following Table. Most of the tramways mentioned had only been opened a short time, but the accounts, so far as rendered to December 1881, were given. Of 193 miles constructed the accounts of the cost of 142 miles were stated as £400,455 or £2,822 per mile. Leaving out the Saronno-Como line, of which the mileage receipts and expenses alone were given at

Mr. Gordon.

THE TRAMWAYS of LOMBARDY in 1880–81;

Name of Tramway Company.	Places between which the Lines are Run.	Length of Lines.	Date of Concession.	Original Cost.				
				Way and Works.	Stations, &c.	Rolling Stock.	Other Items.	Total.
		Metres.		Francs.	Francs.	Francs.	Francs.	Francs.
Società Anonima del Tramway .	Milano–Vaprio .	28,713	1877	499,309	184,807	342,509	29,549	1,371,477
	Cascina Gobbu-Vimereata	15,126	1880	289,964	25,339			
	Milano–Castano .	44,100	1878	1,056,000	57,400	251,000	45,600	1,410,000
	Monza-Barzano .	20,000	1879	992,183	..	152,318	42,186	1,237,487
	Saronno–Como .	23,800	1880	1,199,000	100,000	365,000	56,000	1,720,000
Società dei Tramways di Roma, Milano, e Bologna . . .	Milano–Tradate .	24,315	1876	..	..	..	..	..
	Milano–Gallarate	35,553	1880	..	..	..	..	..
The Tramways and General Works Co. .	S. Angelo–Soncino .	19,000	1878	810,000	270,000	240,000	102,400	1,422,400
	Milano–Giussano	27,500	1878	..	..	..	..	..
	Lodi–S. Angelo	13,000	1878	..	..	..	..	..
Cav. Ferdinando Pistorius . .	Lodi–Treviglio	3,706	1879	..	..	..	..	..
	Milano–Lodi .	29,690	1879	1,000,000	300,000	250,000	50,000	1,600,000
	Melegnano–Slergilo	16,535	1880	..	..	..	..	..
	V. Fornaci–Treviglio	8,970	1880	..	..	..	..	..
Société des Tramways de la Haute Italie .	Milano–Pavia .	18,046	1879	850,000	120,000	225,000	55,000	1,250,000
	Total kilometres .	328,054	..	..	..	..	..	..
	Total kilometres .	228,653	..	..	Accounts	rendered;	costing	10,011,364
	Miles	142,085	..	..	..	..	Costing	£400,455

with STATEMENT OF ACCOUNT to DECEMBER, 1881. Mr. Gordon.

Income in 1881.				Expenses in 1881.				
				Repairs.				
Passengers.	Goods.	Other Items.	Total.	Rolling Stock.	Way and Works.	Staff, &c.	Fuel, Wages, &c.	Total.
Francs.	Francs.	Francs.	Francs.	Francs.	Francs.	Francs.	Francs.	Francs.
271,087 47,822	8,874 1,819	15,288	344,890	49,281	44,555	21,294	154,670	269,800
196,435	10,062	3,516	210,013	11,164	7,299	78,424	46,843	143,730
115,090	8,990	2,234	126,314	10,048	7,190	58,247	37,567	113,052
..	Per kilometre		[13,500]	..	..	Per kilometre		[4,850]
164,050	8,452	14,462	186,964	..	..	..	..	148,720
281,890	5,861	11,622	299,373	..	..	..	..	167,198
150,900	18,000	1,600	169,600	15,000	3,600	65,000	15,000	98,600
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	[263,168]	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
137,697	4,189	..	141,886	..	..	..	..	67,109
..	..	..	..	..	..	..	..	..
..	With receipts		1,742,211 1,479,040	..	..	And expenses		1,008,209
..	..	..	£59,162	..	..	..	..	£40,328

Mr. Gordon. £540 and £194 respectively, and the Milano-Lodi line, of which the expenditure was not given, the total receipts for 1881 of the remaining 109 miles amounted to £59,162, the expenses of the same to £40,328, and there was a balance of £18,834 to pay the returns on £267,655, the capital cost of these lines, or a little over 7 per cent.

Mr. Gumbley. Mr. W. GUMBLEY stated that the traffic on the Guernsey Steam Tramway had been worked exclusively by steam since its opening on the 6th of June 1879. In his opinion engines of the power required for this class of work, could not be worked and maintained for an indefinite time, under ordinary circumstances, at a cost much less than 6*d.* per mile run. The engines employed at Guernsey were direct-acting high-pressure, condensing or non-condensing as desired, with inside cylinders 7 inches in diameter and 12 inches length of stroke. Four of the engines had been built by Mr. Hughes of Loughborough, and two by Messrs. Merryweather and Sons. An engine of similar dimensions, but driving on to an independent crank-shaft coupled to the outside connecting-rods, built by Mr. Lewin of Poole, was employed for the first two years, but had been condemned and broken up on account of the expense of keeping it in repair. The trains usually consisted of the engine and two carriages carrying about sixty inside passengers. The line for about one-half its length was on the public roads, the remainder being a light railway on the company's own land. Only a small portion of the line in the street was pitched, the remainder was granite macadam. When the loads were such as were hauled by the engines at Sydney, steam-locomotives might be profitably employed, but not where the traffic could be efficiently worked by two-horse cars. Repairs and renewals, such as new fire-boxes, tubes, crank-axles, &c., could not in his opinion be provided out of the small sum per mile mentioned by Mr. Parsons.

Mr. Herbert. Mr. GIDEON HERBERT remarked that there were very few tramways in the United Kingdom where the rails were equal to the increased wear which steam traction would inflict. Even those recently constructed for this class of business were not, in his opinion, durable enough; besides, the formation of the roadways was at present a doubtful matter. But supposing these to be right, not many of the existing tramways could bear the burden of a depreciation charge amounting to three per cent. per annum upon the cost of the permanent-way, admitting that sum to be sufficient.

Dr. Hopkinson. Dr. J. HOPKINSON observed that both the Papers under discussion showed that steam-tramways possessed a great advantage over traction by horses in the matter of economy; but they also showed that this advantage was not attained without serious counter-balancing disadvantages, and that in order fully to secure the economic advantage of steam the cars should be large, holding sixty or ninety passengers; it was also necessary that the ratio of dead weight to live weight should be high. The great weight of engine and car necessitated more substantial rails and higher cost in every part of the laying of the road. The high ratio of dead weight to live weight demanded an expenditure of extra power, which might render the actual haulage more costly than with a more expensive power requiring a lighter car. The great capacity of the cars led to their being run at less frequent intervals; now one advantage which tramways possessed was that the unit was small, and that consequently low velocity was compensated by frequency, and that therefore the time required to get from one place to another was on the average small. Probably any kind of haulage on the public roads more or less interfered with the use of the road for other purposes; the mere existence of the rails of a tramway did so. It became then a question of a comparison between advantages gained by improving the use of the tramway against advantages lost by interfering with the other uses of the road. The economical advantages of steam-tramways could be, and had been, realized and exceeded by tramways electrically driven, and electrically driven tramways need not require either heavier rails, larger cars, or a higher ratio of dead to live load than horse-tramways. Various plans of driving tram-cars electrically had been tried. Many attempts had been made to use accumulators, but without practical success; even if partial success were attained, the great dead weight of the accumulators would be a serious drawback. The two rails had been used as the positive and negative conductors carrying the current from fixed dynamos at a distance. This was tried, in the first instance, at Portrush, but without satisfactory results owing to the length of the tramway, nearly 7 miles. Complete success had been afterwards attained by using a separate rail insulated at a small height above the ground as one conductor, and the two rails as the return. The work had been carried out by his brother, Dr. Edward Hopkinson, under the late Sir William Siemens. This method could not conveniently be used in towns. It was, however, possible to arrange a conductor in such a way as to interfere very little with the use of the road for other purposes, quite free from danger, at the same time attaining a high efficiency. Mr. Parsons estimated that twenty-five cars for sixty passengers

Dr. Hopkinson.

Dr. Hopkinson. and twenty-five engines would cost £25,750. For the sake of comparison he had made a rough estimate of the cost of twenty-five cars of equal capacity (though of course they would weigh much less than the steam-car and engine) of the motor dynamos on the cars of the conductor, insulated and fixed for 8 miles of double rail, of adequate generating dynamos, steam-engines and boilers. The result was that the total amount was only about two-thirds of the above sum. The permanent part of the tramway would also cost less. The consumption of coal would probably be less, owing to the lighter weights to be propelled, and to the fact that stationary engines of comparatively large power would be employed. With electricity smaller cars would be preferable, so as to give a more frequent service, though this would depend upon the character of the traffic. Where there was water-power within 2 or 3 miles of the tramway the expense of working could be greatly diminished, and if the water-power were favourable, as regarded the height of the fall and other circumstances, the first cost would also be less. It was not probable, unless revolutionary discoveries were made, that electrical-traction would ever be substituted for locomotives on ordinary railways; but for tramways, and for overhead and underground railways, it offered advantages possessed by no other method, and these advantages were increased where gradients were severe, curves quick, or where water-power was available.

Mr. Nicolls. Mr. Thomas J. Nicolls said that in both Papers it seemed to be inferred that the question was merely that of the special advantage of steam-power applied to tramways, and it had been overlooked that there might be disadvantages in its application, as well as circumstances in particular localities, rendering the use of steam and of certain forms of engine or car undesirable. For instance, Rowan's combined engine and car would be as impracticable on some of the routes of the Manchester, Leeds, Birmingham, Metropolitan, and other systems as it was on the Vale of Clyde line between Glasgow and Govan; at which termini the engines were detached from one end of the car, run round, and attached to the other end, while the arriving passengers alighted and others took their places. At certain hours cars started, as many as one or more per minute: it was obvious that with such a traffic the combination car and engine, requiring ten minutes to detach and re-attach, would be wholly impracticable. Just as in the case of railways, the development of traffic had led to the adoption of larger and heavier cars, at first without alteration of the motive power; but the adaptation of steam-power both to haulage and stoppage of cars, had altered the conditions under which tramways were originally laid. As a consequence a heavier rail, rolled in longer lengths, thus having fewer joints, and with improved sleepers and chair fastenings, had been adopted, entailing a more costly road both as regarded prime cost and maintenance; yet the life of the permanent-way could not but be prejudicially affected by the greater weight of the cars, the extra tonnage and wheel-mileage of the engines, and by additional wheel-mileage, when cars were fitted with four-wheeled bogies at each end. On railways, at junctions, and at stations where fast trains stopped, the life of rails had been reduced in some cases as much as 70 or 80 per cent. by the use of the modern quick-acting continuous brakes. Tramway-rails must suffer more or less in like manner from the causes enumerated. It might therefore be expected that, while capital outlay per mile was heavier, maintenance charges would at least not diminish; and that the reserve fund, based on an estimate of only 3 per cent. per annum for depreciation, and supposed to accumulate at 5 per cent. per annum interest, would be inadequate to satisfy the more frequent demands for renewals. All routes were not, physically, nor were all commercially, suitable for the use of steam. For instance, on the Bury and Tottington line in Lancashire, not only did the tractive power of the engines frequently fail to bring the cars up the hills, but the brake-power was insufficient to prevent the cars from running back. The permanent remedy for these defects could, it would seem, only be effected at an undue increase of capital expenditure. Again, the coal of the district was unsuitable for tramway purposes; the sulphur fumes were to be seen encrusted on the exterior of the engine funnels; and on the main line from Manchester (Broughton Bar) to Bury, as a protection against them, for outside passengers, the Board of Trade had required a second roof with a screen to be added to each car. This, however, did not entirely fulfil the intended purpose, and it was doubtful whether any benefit derived balanced the cost involved. In the absence of the screens there was unquestionably a loss of revenue to the company, as the public would not go outside, preferring to walk rather than pay the larger fare for inside seats, which was their only alternative. On lines situated such as this, horse-power would probably prove more profitable. The route instanced had made, prior to the introduction of the tramway, a good return to the owners of a system of well-horsed omnibuses, while as a tram-line it was believed not to earn any return on its proportion of capital outlay. To the foregoing considerations might be added

Mr. Nicolls.

Mr. Nicolls. that of the increased danger to the public by reason of horses using the road being frightened; many fatal and minor accidents from this cause had been recorded. In certain districts these would be frequent; consequently the growing item of "damages" would be an additional drag on the revenue of tramway companies.

It had yet to be seen how far tramways in populous districts could, consistently with public rights and convenience, be made use of for other than passenger traffic. Many efforts had been made to obtain the sanction of Parliament to such measures as would empower companies to convey heavy merchandise and mineral traffic along the public highways; but, so far, the intervention of local authorities had generally succeeded either in having such powers excised, or in placing such restrictions on their use as practically to render them inoperative. Should the time come when the roadways of the kingdom might be converted into a competitive system of railways, free from the enormous cost of providing land, it would be under conditions that many of the present objections to the universal adoption of steam would be removed, and a balance of advantages instituted which did not now seem to exist. Before the advent of such an era, it was likely that electricity would have overtaken its elder rival, and won the field.

Mr. Shellshear. Mr. W. SHELLSHEAR remarked that, since the preparation of his Paper on the Sydney steam-tramways, additional information had been published in the report of the Commissioner for Railways of the Colony for 1883.[1] The returns showed a large increase of business as compared with 1882, the traffic having increased from 15,269,100 fares collected in 1882 to 25,713,433 in 1883. The number of passengers might be taken as approximately two-thirds the number of fares, the fares being collected separately on the different sections. The net earnings, however, had decidedly fallen off; and this was to be accounted for through the excessively heavy traffic upon the lines. The traffic had developed so rapidly, that the resources of the department had been unable to keep pace with it; consequently both the roads and the rolling-stock had received scarcely any repairs. The working expenses had increased enormously, and out of proportion to the revenue. This falling off was not to be attributed to the steam-tramway system, but to the work to be done having outgrown the appliances at command. The traffic had been so great as to necessitate the motors being kept upon the road under any circumstances, extensive repairs having to be done at great expense by night, so that the motors might be available in the morning. This could have no other result than reduced profits. Experience had still further proved the necessity of devoting the greatest attention to the design of permanent-way for steam-tramways, and that no idea of economy in first cost should prevent the introduction of the most substantial description of road. Mr. Shellshear.

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[1] See *ante*, p. 127.

At present the road was being strengthened in some places by heavy longitudinal sleepers bedded in cement concrete, in place of the cross-sleeper road previously described. The roadway laid with the 70-lb. rail had stood the traffic remarkably well, and was nearly as good as new. He thought that with adequate rolling-stock to allow of a reserve, so that repairs might be executed without having recourse to hurried and expensive night-work, and with improved permanent-way, the steam-tramway system of Sydney, while affording immense convenience to the public by cheap and rapid transport, would return a fair dividend upon the capital expended. The following was a summary of the returns for the year 1883:—

Average ordinary day's traffic, 92,647 fares collected, representing 65,320 passengers. Heaviest day's work on public holiday, 168,063 fares, representing 104,448 passengers. Total passengers' fares collected, 25,713,433, being an increase of 10,417,194 on the number for 1882. Eleven persons were killed and forty injured by the trams in 1883, being in the proportion of one person killed to every 2,337,585 fares. Fifty-eight engines were in use at the end of 1883. The average distance run by each motor was nearly 25,000 miles. Ninety-eight cars were employed, which would accommodate 7,020 passengers. At the end of the year a length of 22 miles had been open for twelve months, 1¾ mile for eleven months, and 1¼ mile for six and a half months. The average fare charged on the tramway was about 1*d.* per mile; the fares were collected in two-penny sections; which, considering the high cost of every description of labour, might be considered very reasonable.

Mr. J. A. Wright observed that experience with steam on French tramways had not been of a nature to promote its general adoption, it having proved a failure, to such an extent, that in most cases it had been abandoned, and horses substituted as more economical. Thus, on the tramways Nord de Paris, where engines had been employed for a considerable time on the line from the Barrière de l'Etoile to Courbevoie, the Company was compelled to give them up and revert to horse-traction, owing to the excessive cost. This, in the year 1881, amounted to 81·60f. per engine per Mr. Wright.

Mr. Wright. diem, and to 1·0059f. per car-kilometre, or 16·095*d.* per mile for traction alone, no allowance being made in these figures for depreciation.

The items of this expenditure were—

—	Total.	Per Car-Kilometre.	Per Car-Mile.
	Francs.	Franc.	*d.*
Wages, drivers, firemen, &c.	75,908·98	0·2401	3·841
Coke, oil, &c.	81,882·02	0·2590	4·145
Repairs to engines	134,458·10	0·5068	8·109
Renewal of engines	26,238·71		
Totals	318,487·81	1·0059	16·095

The engines were given up in 1882, when the cost of traction was reduced to an average of 0·5439f. per kilometre, or 8·70*d.* per mile.

In 1879–80, Mr. Hughes, of Loughborough, undertook the traction with locomotives on the tramways Sud de Paris, on the line from the Place de la Bastille to Charenton, at the rate of 0·45f. for one car, and 0·60f. for two cars per engine, equal to 7·20*d.* and 9·60*d.* per mile respectively. After a few months, he was forced to abandon the attempt owing to the excessive cost, which averaged 0·5891f. per kilometre, or 9·425*d.* per mile, without counting either interest on the capital invested or depreciation. The item for repairs alone amounted to 2·702*d.* per mile, although the engines were new and of an improved type.

Undismayed by his want of success in Paris, Mr. Hughes took in hand the traction on the Lille tramways, at the same rate per kilometre as before. He was again compelled to give it up owing to the cost, which amounted to 0·5985f. per kilometre, or 9·577*d.* per mile on the Haubourdin line, and 0·5915f. per kilometre, or 9·465*d.* per mile on the Roubaix. The repairs again came to 2·892*d.* per mile in the former, and to 2·245*d.* in the latter case, although, as in Paris, with new engines, built specially for the line. The Lille Tramways Company had since abandoned steam-traction on their Haubourdin line, and had adopted for that from Lille to Roubaix Mr. Francq's system of "Fireless Locomotives," which appeared to be doing satisfactorily.

On the Rouen tramways, engines had been worked on the Maromme-St. Hilaire lines since 1878. The engines were of five

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different types, and had for the most part seen considerable service and rough usage on the tramways Sud de Paris, under Mr. Harding's original contract, before being sent to Rouen. The average cost of steam-traction taken over a period of three years (1881-83), during which a total of 591,205 miles were run by the engines, was 0·6854f. per kilometre, or 10·966*d.* per mile, including, however, all charges incidental to the traction.

The cost per engine-kilometre per year was—

——	1881	1882	1883
	Franc.	Franc.	Franc.
Wages—foreman, store's clerk, coke and yard men, night-fitters, &c.	0·0410	0·0296	0·0274
Ditto, drivers and firemen	0·1679	0·1679	0·1544
Premiums—mileage and coke	0·0177	0·0172	0·0147
Coke, oil, tallow, waste, &c.	0·2220	0·1983	0·2249
Octroi on coke, &c.	0·0120	0·0120	0·0120
Water	0·0037	0·0025	0·0059
Rent of engine depôt and shops	0·0124	0·0079	0·0101
Gas for ditto	0·0099	0·0084	0·0085
Repairs to ditto	..	0·0013	0·0018
General charges	0·0031	0·0017	0·0060
	0·4897	0·4468	0·4657
Repairs—wages	0·1106	0·1031	0·1327
" stores	0·0948	0·0942	0·1187
Total cost per kilometre	0·6951	0·6441	0·7171
	d.	*d.*	*d.*
Or per mile	11·121	10·305	11·473

In the above statement, it would be observed that everything connected with the locomotive service, such as rent of depôt, repairs to buildings, gas, octroi, &c., had been included and reduced to a charge per kilometre. Had these been omitted, so as to permit of a comparison being made with the returns of other companies, the average cost of traction for the three years would have been 0·6170f. per kilometre, or 9·872*d.* per mile. The cost of repairs to the engines amounted to 3·286*d.* per engine-mile in 1881; to 3·156*d.* in 1882; and to 4·022*d.* in 1883. In this last year, the greater part of the engines were, however, re-tubed. It must be remembered that these engines had for the most part seen long service under most unfavourable conditions.

The foregoing statements and figures, as compared with the cost of steam-traction in England, and with more recent experience in France even, showed that there was, or rather had been

Mr. Wright. up to very lately, something radically wrong in the tramways in France, as otherwise, with the exception of a slight increase in the cost of fuel, &c., and from the authorities wisely requiring a fireman on the engine as well as the driver, there was no reason why the results should not have been similar in the two countries. In addition, the Government and local authorities in France were much more liberal in their views and more lenient in their requirements than in England. Engines were not, except in very exceptional cases, required to condense their steam, even in the streets, and this formed an element of economy in working.

The causes of failure were—first, that the engines were incapable of doing the work they were called upon to perform; and secondly, defects in the permanent-way. The first locomotives employed by Mr. Harding on the tramways Sud de Paris, and of which six were afterwards sent by him to the Rouen company, weighed only 3½ tons when empty, and 4 tons when in working order. This weight had been increased in subsequent engines to 5½ tons, and at the same time the diameter of the cylinders from 6 inches to 7 inches. The locomotives built by Mr. Hughes, in 1879, for the tramways Sud de Paris, from the Place de la Bastille to Charenton, weighed 5½ tons when empty, and 7½ tons when in working order, and had 7-inch cylinders. Those for the Lille tramways had 9-inch cylinders, with wheels 3 feet 6 inches in diameter, and weighed 7½ tons when empty, and 10 tons when in working order. The weight of the engines was purposely kept as low as possible, so as not to injure the delicate structure of the road. As a necessary condition, the bearing-surfaces were so small, and the working-parts so slight, that they were unable to stand the rough usage to which they were subjected on a tramway, exposed to dust and grit, and with a bad road to run on. They would, however, have lasted longer, and done better, had the permanent-way been more substantial, and to this might be attributed the failure of steam-traction, so far, in France. The road, far too light at the outset, generally of faulty design and construction for what it had to carry, became out of repair in a very short time, in most cases irretrievably so; but not before, unfortunately, it and the rolling-stock, and in a great measure, the future of the tramway and the sanguine hopes of the promoters of the new traction, of which so much was expected, had been destroyed.

On the Paris and Rouen tramways, the permanent-way consisted of a grooved steel-rail, fastened by side-spikes to a longitudinal-sleeper, supported on cross-sleepers 5 to 6 feet apart, but without tie-rods to keep the road to gauge. In a short time, Mr. Wright. under the weight of the engines, the road began to spread, the consequence being, that the rails were crushed out of shape. To what an extent this had taken place would be seen from Figs. 14, 15, 16, and 17, showing some sections of rails taken up from the Rouen steam line, after only five years' working, and this despite all the care and expenditure bestowed upon the road. To have restored the permanent-way to its proper gauge, and to have added tie-rods to maintain it so, would have involved not only relaying the road, but repaving for its entire length, and have led to an expenditure out of the question; so nothing could be done but to patch up the worst places. At last, it became imperative either to relay the road properly from end to end, and purchase new engines more fitted for the work in place of those by this time completely worn out, or to stop the steam-traction. Few, if any, of the companies were in a financial position to permit of their doing the former, and the alternative of reverting to horse-traction had to be accepted, notwithstanding the further large expenditure on an already overcharged capital account; with the evil day when the road must be relaid, only postponed for a

FIG. 14.

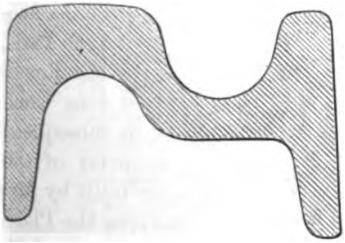


FIG. 15.

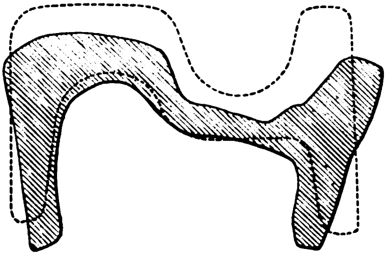


FIG. 16.

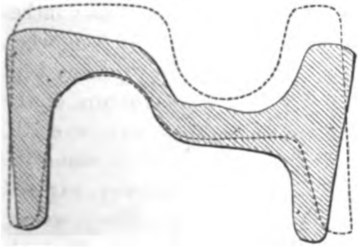
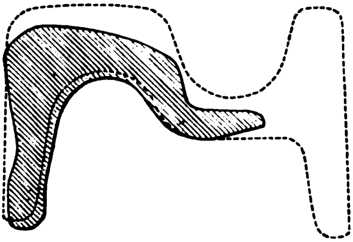


FIG. 17.



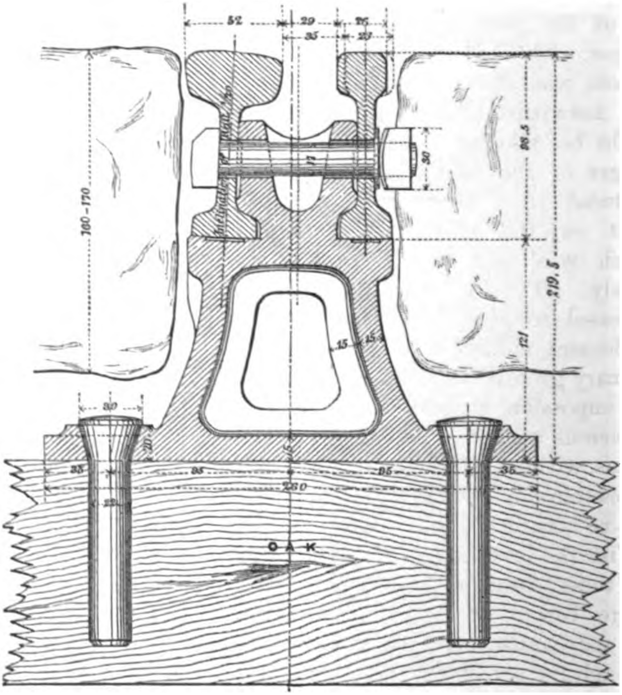
Scale ¼ inch.

Fig. 14, Original Section, 1878. Fig. 15, Maromme Line, Sept. 1883. Fig. 16, Maromme Line, Sept. 1883. Fig. 17, Barrière du Havre, Oct. 1883.

Mr. Wright. season, and until such could be done, with an enormously increased traction for the horses, and damage to the cars.

At Rouen, a portion of the permanent-way had been relaid with a modification of Marsillon's, or the level-crossing system of road, which consisted of a rail and counter-rail carried on cast-iron chairs fastened to transverse sleepers. The characteristics of this road (Fig. 18), consisted in the suppression of the longitudinal timber, and the employment of separate rails and counter-rails. By this means, an open groove was left between the rails. This allowed of the water draining away at the bottom, carrying with it all detritus and dirt, which on an ordinary grooved rail caused so large an additional resistance to traction. Other sections of rails for the Rouen steam-tramways were shown by Figs. 19, 20, and 21 (p. 211). Fig. 19 represented the section of a rail in the straight, Fig. 20 through a joint of the rail, and Fig. 21 through a joint of the counter rail.

FIG. 18.



Scale ¼ inch.

Mr. Wright.

FIG 19.

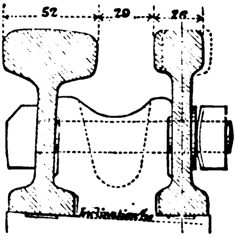


FIG. 20.

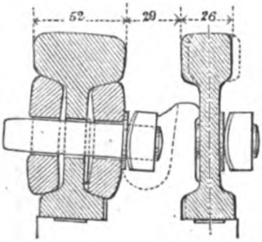
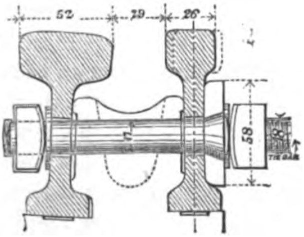


FIG. 21.



Scale ¼ inch.

The timber longitudinal-sleeper, the essential element in most tramway-roads in France, by the constant variations from dryness to excessive moisture, soon got out of shape, which led to the rail also being affected. The passage of the engines and cars and the heavy street traffic set up a vibration in the spikes and fastenings; water then entered, the timber rotted, and the spikes remained more as a matter of form than for any practical use; the constant re-spiking served the more quickly to destroy the sleeper. The groove, being closed at the bottom, was always filled with dust and dirt, notwithstanding all the care that might be taken to keep it clear. The flanges of the wheels ran on this, and produced in a short time a crushing effect on the bottom of the groove, which was soon worn through completely. To this must be added the increased traction, and the uneven and unpleasant motion of the car. With an ordinary grooved tramrail, as described, it was impossible to obtain an effective fish. Numerous trials had been made to arrive at this, without which steam-traction was impossible; but owing to the shape of the rail, no lasting result had been attained.

With the level-crossing system of road, all these disadvantages were avoided. There being no longitudinal timber, the rod could not get out of shape through its warping; there was no closed bottom to the groove; consequently the flanges of the wheels could not wear on it, with the result of increased durability, both to the road, to the wheels, and to the rolling-stock generally, a more easy motion to the car, and a considerable decrease in traction. The fishing of the rails was as perfect as on a railway, and could be made either as a suspended joint or on a chair. In addition, a rail might be taken out, and either changed end for end or another substituted in a few minutes, even without, in ordinary cases, interfering with the traffic.

The permanent-way, as laid at Rouen for the new roads, con-

Mr. Wright. sisted of a steel-rail weighing 16·350 kilograms per metre (33 lbs. per yard), and a counter-rail weighing 11·650 kilograms (22½ lbs. per yard). This latter was rolled unsymmetrical, so as to allow of an increased width of groove in curves, and consequently a diminished traction, the regulations of the French Ministry of Public Works permitting a width of groove of 29 millimetres (1·14 inch) on the straight, and 35 millimetres on curves. The chairs, weighing 8 kilograms (17·6 lbs.) each, were placed at distances of 0·925 millimetre from centre to centre, except at the joints, where they were 0·605 millimetre. They were fastened to the transverse sleepers by compressed oak trenails, which was the first time that this well-known system of fastening had been used in France. The sleepers were of oak, 2 metres (6 feet 6 inches) long, 16 to 20 centimetres (6·3 to 7·9 inches) wide, and 10 to 12 centimetres thick. The rails were 8 metres long, and in each length of metals there were three tie-rods of an oval section, so as not to interfere with the paving. The switches and crossings were similar to those on a railway, the former being made automatic by means of a counter-balance weight laid in a cast-iron box under the road. The road approached closely to a railway in construction, and was sufficiently strong to bear the heaviest traction likely to come upon it. From the shape of the rail, and the manner in which it was laid, the tractional force required was reduced to a minimum, and was less than one-half what it was on an ordinary grooved tramrail.

More recent experience with steam-traction on tramways in France had given much better results than those before mentioned; every care having been taken to provide both a substantial road and properly designed locomotives. On the tramways of Valenciennes-Anzin, of which a length of 38,300 metres was now open for traffic, the gross receipts in 1883 were 358,696·06 francs, with a total expenditure of 217,739·96 francs, the working-rate having been, therefore, as low as 60 per cent. of the receipts. These averaged 17·60*d.* per mile, and the expenses 9·76*d.* The engines, of which the Company had at present seventeen, were built by the Société Métallurgique of Toubize (Belgium), and were six-wheeled coupled, weighing 16 tons in working order.

On the tramways of St. Etienne, Firminy, and Rive de Gier, of which a length of 38,620 metres was open, the receipts were 1,101,429·10 francs, and the expenses 968,716·65 francs, a working-rate, therefore, of 88 per cent. Although this was high compared with the Valenciennes-Anzin results, it was better than for many of the other French Companies. It would have been

Mr. Wright.

more so, were it not that the fares, as provided by the concession, were far too low. The receipts averaged 20·768*d.* per train-mile, and 7·920*d.* per car-mile; the expenses 17·520*d.* per train-mile, and 6·697*d.* per car-mile. The expenditure was thus made out:—

——	Per Train-Mile.	Per Car-Mile.
	d.	*d.*
Administration	4·880	1·872
Traffic	2·368	0·912
Traction	7·984	3·033
Repairs to cars, cleaning, lighting, &c. . .	1·536	0·592
Maintenance of permanent way	0·572	0·288
Totals	17·520	6·697

The details of the cost of traction were:—

	d.	*d.*
Wages, drivers, firemen, &c.	2·608	1·008
Premium for economy	0·176	0·064
Coke, coal for lighting, &c.	2·432	0·928
Oil, tallow, waste	0·560	0·204
Water	0·064	0·016
Repairs	2·144	0·813
Totals	7·984	3·033

The permanent-way at St. Etienne was on Demerbe's system of rolled steel trough-rail. Owing, however, to the bad foundation in many places, where the line was laid on the side of the road, and to the scarcity of proper ballast in others, cross-sleepers had since been added, with the object of consolidating the way. The rolling-stock of the company consisted of thirty-four locomotives, ninety-seven cars, and twelve vans. The first engines were supplied by Brown of Winterthur, and by the Société Métallurgique of Toubize, the former being four- and the latter six-wheeled coupled. The engines of both types weighed 11 tons when empty, and 13 tons when in working order. A third, and more powerful type, had since been built by Messrs. Carels frères, of Ghent. These engines were also six-wheeled coupled, and weighed 12 tons when empty, and 15 tons when in working order. The cylinders (outside) were 0·270 metre in diameter, with a length of stroke of 0·350 metre; the wheels were 0·800 metre in diameter. The fire-box surface was 2·50 square metres; there were seventy tubes, 45 millimetres in diameter outside, giving 24·50 metres surface, the total heating surface being therefore

Mr. Wright. 27 square metres. The extreme length of the engine was 5·180 metres, and the wheel-bases 1·800 metre. These engines took, easily, three loaded cars up the long inclines at Rive de Gier and Lorette, the gradients of which were 1 in 14.

There could be but little doubt that steam-traction, especially where the distances were long and the traffic heavy, must eventually supersede horses; but in order that it might prove a success commercially, a steam-tramway must be properly constructed and equipped at the outset.

One of the essential points towards economy in working was, as Mr. Parsons had observed, that the company must possess a sufficient number of engines, to render it unnecessary to employ them so continuously as to lead to the neglect of ordinary repairs. This, an absolute necessity, had generally so far been ignored by tramway companies from financial reasons, with the result that engines in urgent want of repair often had to be used, owing to there being no others to take their place. Never was the old saw of a stitch in time saving nine better exemplified than in the case of steam-tramways; but if the number of engines at the manager's disposal was so limited, as it usually was, as to prevent the proverbial stitch being given, directors must not be astonished if, at the end of a certain period, the cost of repairs, done at night or in haste, were expressed in pounds instead of shillings, and that in a comparatively short time new engines had to be provided, generally to a larger extent than would have been necessary had the number been sufficient at the outset.

No doubt steam-traction was generally preferred to horses by the travelling public, and, although contrary to general belief, there was a far greater immunity from accidents than with horse-traction. At Rouen, where both systems were used, the proportion was very great. There, notwithstanding that the engines were non-condensing, and that steam was exhausted freely, even in the most crowded thoroughfares, rarely was a horse frightened, and when this did happen, it was in most cases the fault of the driver. With crowded streets, steam-cars could be worked through more quickly and with greater security than horses, in proof of which, at Rouen, during the fêtes, &c., engines, owing to their being more under control, were always allowed to circulate by the police authorities as at ordinary times, when the horse-cars were strictly prohibited. Again, engines generally ensured better time being kept with the trains. Horses could not be pushed beyond their pace, and if a car was delayed the service suffered; whereas with engines the time lost might always, to a great extent, be made up, and the crossings effected properly at the passing-places, thus avoiding delay. Mr. Wright.

There were doubtless certain disadvantages in the use of steam. If an engine got off the road, it took a good deal longer to get it on again than to "jump" an ordinary car; or, if an axle broke, the road was blocked for a considerable time, and the service interrupted until it could be cleared. But these were not of frequent occurrence, and might, the latter especially, generally be avoided with careful supervision and management, provided always the number of engines was sufficient to allow of this being effected.

9 and 16 December, 1884.

SIR J. W. BAZALGETTE, C.B., President,
in the Chair.

The discussion upon the Papers, by the Hon. R. C. Parsons on "The Working of Tramways by Steam," and by Mr. Shellshear on "The Sydney Steam-Tramways," occupied both evenings.

ANNUAL GENERAL MEETING.

23 December, 1884.

Sir J. W. BAZALGETTE, C.B., President, in the Chair.

THE notice convening the meeting having been read,

Messrs. A. T. Atchison, G. Chatterton, C. H. Cooper, F. S. Courtney, J. M. Dobson, C. Frewer, H. G. Harris, C. E. Hollingsworth, E. Perrett, W. Shield, and T. M. Smith, were requested to act as Scrutineers for the election of the President, Vice-Presidents, and other Members of the Council for the ensuing year; and it was resolved that the Balloting lists should be sent to the Scrutineers for examination at intervals.

The Ballot having been declared open, the Secretary read the Report of the Council upon the proceedings of the Institution during the year 1884, and upon its general condition.

The Telford Medals, the Telford and Manby Premiums, and the Miller Scholarship and the Miller Prizes, for 1884, which had been awarded, were presented. (Pages 230, 231.)

Resolved,—That the Report of the Council be received and approved, and that it be printed in the "Minutes of Proceedings" in the usual manner.

Resolved,—That the best thanks of the Meeting be accorded to the Vice-Presidents and other Members of Council, for the time and trouble they have bestowed in promoting the objects of the Society.

Sir Frederick Bramwell, Vice-President, returned thanks.

Resolved unanimously,—That the hearty thanks of the members be tendered to Sir J. W. Bazalgette, President, for the great attention he had paid to the duties of his office, and for the manner in which he had devoted himself to the interests of the Institution.

Sir J. W. Bazalgette, C.B., President, returned thanks.

Resolved,—That the members of the Institution desire to record the sense of their indebtedness to each of the Lecturers on "Heat in its Mechanical Applications."

Mr. W. Anderson returned thanks.

Resolved,—That the thanks of the Institution be presented to Messrs. H. M. Brunel and Edward Bazalgette, the Auditors, for the careful manner in which they had examined and audited the accounts; and that Messrs. Edward Bazalgette and H. Bauerman be requested to act as Auditors for the ensuing year.

Mr. Brunel returned thanks.

Resolved,—That the thanks of the members be given to Mr. James Forrest, the Secretary, for the energy, ability and integrity which he continued to show in the performance of his duties.

Mr. Forrest returned thanks.

The Scrutineers then announced that the following gentlemen had been duly elected:

President.

SIR FREDERICK J. BRAMWELL, F.R.S.

Vice-Presidents.

Edward Woods.
George Barclay Bruce.
Sir John Coode.
George Berkley.

Other Members of Council.

Benjamin Baker.
John Wolfe Barry.
Sir Henry Bessemer, F.R.S.
Edward Alfred Cowper.
Sir James Nicholas Douglass.
Charles Douglas Fox.
Alfred Giles, M.P.
Harrison Hayter.
William Pole, F.R.SS. L. & E.
William Henry Preece, F.R.S.
Sir Robert Rawlinson, C.B.
Sir Edward James Reed, K.C.B., F.R.S., M.P.
Francis Croughton Stileman.
Sir W. Thomson, F.R.SS. L. & E.
Sir Jos. Whitworth, Bart., F.R.S.

Resolved,—That the thanks of the Meeting be given to the Scrutineers, for the efficient manner in which they had discharged their task; and that the Ballot-Papers be destroyed.

REPORT OF THE COUNCIL FOR 1884.

At this, the Annual General Meeting of Corporate Members, the Council is required to present a report on the state of the Institution, with an account of the Funds and of the Receipts and Payments during the past year.

THE ROLL OF THE INSTITUTION.

It may be convenient to take, as a starting point, the condition of the Institution when the present By-laws were enacted on the 2nd of December 1878. Then the strength consisted of 1,061 Members, 1,738 Associates, and 16 Honorary Members: now the numbers are 1,416 Members, 1,844 Associate Members, 502 Associates, and 20 Honorary Members; so that, in the interval of six years, there has been an increase of 34 per cent. During the past session 2 Honorary Members, 51 Members, 219 Associate Members, and 13 Associates were elected, and 1 Member and 3 Associates were restored to the Register, together 279; while the deceases, resignations, and erasures in the past twelve months have been 85, leaving a net increase of 194, or 5½ per cent.[1] In this calcu-

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[1] The changes that have occurred during the past twelve months are shown in the following Table:—

—	Nov. 30, 1882, to Nov. 30, 1883.					Nov. 30, 1883, to Nov. 30, 1884.				
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers at commencement	20	1,307	1,536	522	3,385	20	1,355	1,701	512	3,588
Transferred to Members	..	40	40	..		..	44	44	1	
Do. to Associate Members	..	..	4	4		..	..	3	3	
Elections	1	41	223	15	283	2	51	209	13	279
Restored to Register	..	..	3	..		..	1	3	..	
Deaths	1	26	15	11		2	28	14	10	
Resignations	..	5	6	5	−80	..	6	7	6	−85
Erased	..	2	4	5	203	..	2	7	3	194
Numbers at termination	20	1,355	1,701	512	3,588	20	1,416	1,844	502	3,782

lation the Students are not included. Of the present number of Associate Members 823 belonged to the original class of Associates, and of the existing Associates 75 are not entitled to the privileges of Corporate Membership.

The number of members of late years has been increased largely from Candidates resident beyond the sea—for example, 100 out of the 279 elected last session were not resident in the United Kingdom—a proof that Engineers in the Colonies are well satisfied with the way in which the affairs of the Institution are conducted and administered, and that the position and work of the Institution are by them thoroughly appreciated.

ADMISSION OF STUDENTS.

The changes in the class of Students have been numerous. At the end of the last session there were on the books 722; since then 170 have been admitted, and the deductions amounted to precisely

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The list of Deceases is:—

Honorary Members:—The Duke of Buccleuch and Queensberry, K.G., D.C.L., F.R.SS. L. and E.; and *Lt.-Gen. Count* Edward Todleben.

Members: John Hallen Abbott; George Frederick Adams; James Bell; Eugenius Birch; Walter Raleigh Browne, M.A.; Alexander Bryce; Augustus John Darling Cameron, F.R.S.E.; Henry Chapman (*Kennington*); Leslie Clark; Joseph Edward Fisher; Henry Allason Fletcher; Charles Fouracres; Robert Samuel Fraser; Richard Garrett; Francis Giles; Sydney Hall; Henry James Jackson; Andrew Johnston; Henry Batson Joyner; Francis Mackison; Charles Manby, F.R.S. (*Hon. Sec.*); Thomas Martin, B.A.; John James Montgomery; George Henry Phipps, Jun.; Hon. James Henry Thomas; Henry Tomlison; Charles Woodley Whitaker; and John Whitfield.

Associate-Members:—Massey Bromley, M.A.; Alfred Brace Cruse; James Eldridge; William John Jones; John McGlashan; John Napier; Nicolas Ontine; Edward Matthew Park; William de Winton Peel; Mervyn James Butler Pratt, M.A.; Frederick Augustus Sheppard; Graham Smith; Alexander Stark; and Charles Harcourt White.

Associates:—William Brookes; *Sir* Charles James Freake, *Bart.*; John Gordon; Henry Gruning; Spencer Herapath; *Major* Thomas William Kinder; John Horatio Lloyd; *Major-Gen.* Julius George Medley, R.E.; Walter Neilson; and Joseph Robinson.

The Resignations were:—

Members:—Peter Burtchaell; Edward Byrne; Robert Valentine John Knight; Hugh Leonard; William Low; and James Long Parker.

Associate-Members:—Charles Chambers; Robert Messer; Edward Russell Morris; William Nicholl; William Thomas Olive; Thomas Harrison Seacombe; and Robert Sharland.

Associates:—Clement Barnard; *Lt.-Col.* Arthur Edward Downing; Tristic James Ellis; Antonio Gabrielli; *Professor* John Frederick Main, M.A., D.Sc.; and Frederick Stepney Manners.

the same, of which number 71 have become Associate Members, and the remainder have disappeared from the list, mainly by reason of their having arrived at the age of twenty-six years, when the By-laws provide that they must cease to be Students.

Of the 1,964 Students admitted since the creation of the class, seventeen years ago, 46 are now Members, 545 Associate Members, 6 Associates, 722 remain Students, and 645 have ceased to be attached to the Institution.

For some years there has been a desire that the Students' Meetings should be commenced early in the session, that they should be arranged definitely in advance for the whole session, and that they should also occur at regular intervals. Hitherto it has not been practicable to carry out this desire, owing to the limited number of Papers submitted, and to these being sent in late. But as greater activity has recently been displayed by the Students, the Council has sanctioned, as an experiment, the announcement of twelve Supplemental Meetings for the session 1884–85—three before Christmas and nine afterwards, at fortnightly intervals. As far as possible these have been fixed so as to avoid the weeks in which Special Meetings for Lectures will be held. Students, unless resident out of the United Kingdom, are expected to read their own Papers. No Paper will, after the present session, be received from a Student in competition for the Miller Scholarship and the Miller Prizes when he has become qualified by age, viz. 25 years, for election into the Corporation. A reference to the Papers, printed in the Minutes of Proceedings, will afford an indication of the essays that have been deemed worthy of commendation, and these may be taken as examples of what Students should aim to produce. An intelligently-written record of investigations or works upon which a Student has been engaged forms, perhaps, the most appropriate subject for a Paper.

The Council wishes to record its appreciation of the kindness of those engineers who up to this time have afforded opportunities for the Students to inspect works in progress and to visit engineering establishments.

PALMER SCHOLARSHIP.

The Council having accepted the Trust referred to in the Report for the year 1882, a deed was prepared to carry the wishes of the late Mrs. Palmer into effect. This deed is dated the 22nd of January, 1884, and is made between Mr. Cornelius Surgey and Mr. John Bailey Surgey, on the one part, and this Corporation on the other part. After providing for the receipt of the dividends on a sum of £1381 1*s.* 6*d.* Three Per Cent. Metropolitan Consolidated Stock, by Mr. J. B. Surgey during his life, the deed vests the same in the Institution subject to the several trusts therein contained for the endowment of a scholarship to be called the "Palmer Scholarship," according to certain regulations contained in a schedule thereto.

ELECTION OF COUNCIL.

One of the principal objects of the Annual General Meeting is the election of a Council, and at the risk of reiteration the Council at present in office must repeat the explanations of its predecessors in referring to the principles which govern the preparation of the balloting-list. It is sought to make it representative of every branch of engineering, and, as far as possible, of every influential centre of engineering. Irrespective of the President and the four Vice-Presidents, the list, in accordance with the By-laws, contains the names of twenty-four members, while only fifteen have to be returned; but it is competent for the electors to substitute any name or names for those included in the list, provided such substituted names are those of Corporate Members.

DATE OF THE ANNUAL GENERAL MEETING.

As there seems to be a very strong desire, on the part of many Non-resident members, that the day for holding the Annual General Meeting, fixed in the By-laws to take place on the Tuesday previous to Christmas Eve, should be altered, the outgoing Council—while recognizing, as former Councils recognized, the difficulty of selecting a day that will be equally convenient to all the members—expresses the hope that its successors will take into consideration the propriety of altering the day, and will call a Special General Meeting of Corporate Members, at an early and convenient date, to make the necessary alteration in the By-laws.

THE LATE HONORARY SECRETARY.

The death of Charles Manby, at the ripe age of eighty, has removed from among us an old member, and one who took for many years a leading part in the conduct of our affairs. By his tact and energy, at an early and a critical period in the history of the Institution, he managed to secure the co-operation of the principal members of the profession, and of scientific men generally, and thus laid the foundation for its present reputation and success. Mr. Manby was elected into the Institution in 1837, became its Secretary in 1839, and ceased to be its paid officer in 1856, since which up to the date of his death he had been the Honorary Secretary.

At their first meeting after the recess the Council unanimously passed the following resolution:—

"Resolved, That the Council of the Institution of Civil Engineers desires to place on record its high sense of the eminent services rendered to the Institution as a body, and to the members generally, by Charles Manby during the long period that he held the positions of Secretary and Honorary Secretary."

CONTRIBUTION TO THE FUNDS, AND FINANCE.

The Statement of Receipts and Payments, signed by the Auditors shows that the income proper of the year amounted to £14,292 17*s.* 3*d.*, and the expenditure to £12,476 18*s.* 5*d.* To these amounts have to be added, on the receipt side, £3,495 9*s.* derived from Life Compositions and the admission-fees of new members, and £432 11*s.* 2*d.* from dividends on investments under trust, and the balance of £1,110 1*s.* 10*d.* brought forward from last year, raising the gross amount to be accounted for to £19,330 19*s.* 3*d.* On the payment side, a sum of £5,322 3*s.* 8*d.* has been invested, and the cost of premiums under trust was £516 11*s.* 11*d.*; while the balance remaining to be carried forward is £1,015 5*s.* 3*d.*

These figures must be regarded as very satisfactory, and as proving that the steady progress which has characterised the Institution during the last twenty-five years shows no signs of diminution. The most considerable item of expense has been the publication of the Minutes of Proceedings and of the lectures on "The Practical Applications of Electricity," which together absorbed £6,193 15*s.* 5*d.* This amount may appear large, but it should be remembered that it covers the expense of the printing, lithography, and free delivery to members, wherever resident, of some twenty-five thousand volumes, besides the printing of pamphlets, and the provision of the necessary surplus stock, and all expenses connected with reporting, &c.

The invested funds belonging to, or under the control of, the Corporation, amount in the gross to £62,642 13*s.* 10*d.*, of which £48,000 represent Institution-investments, and £14,642 13*s.* 10*d.* bequests and donations under trust. These moneys are placed in Government Stocks or in guaranteed stocks of British Railway Companies.

THE PUBLICATIONS.

The Council is directed to arrange for the publication of the Papers read at the meetings, and of such documents as may be calculated to advance professional knowledge, in aid of the public and scientific objects for which the Society was founded. In pursuance of this obligation, the Council has much satisfaction in referring to the four volumes of Minutes of Proceedings issued during the year, as they necessarily afford the main evidence to distant members of the work of the Institution. These volumes contain not only the Papers read at the Ordinary Meetings, with the reports of the oral discussions and of the correspondence to which they gave rise, but forty "Other Selected Papers," of which five were read by Students at Supplemental Meetings.

The usual amount of space has been devoted to Abstracts of Papers in Foreign Transactions and Periodicals. The correspondence of the Institution shows that these summaries are highly appreciated, especially by members in the Colonies, to whom they often afford the only means of following the progress of engineering in foreign countries.

There has also been issued to every member the series of six lectures on "The Practical Applications of Electricity"—the first lectures ever delivered at the Institution—and this will be speedily followed by the second series given last session on "Heat in its Mechanical Applications."

The Council has had pleasure in awarding the following premiums and prizes:—

For Papers read at the Ordinary Meetings, a Watt Medal and a Telford Premium to Mr. S. W. Barnaby, Telford Medals and Telford Premiums to Mr. S. B. Boulton and Mr. W. Foster, Telford Premiums to Mr. W. T. Douglass, Mr. J. A. Longridge, and Mr. W. Hackney, and the Manby Premium to Mr. G. H. Stayton.

For Papers printed in the Proceedings without being discussed, Telford Medals and Telford Premiums to Mr. T. Andrews and Mr. F. Collingwood, and Telford Premiums to Mr. J. H. Apjohn, Mr. T. Gillott, Mr. J. W. Wyatt, and Mr. W. S. Crimp.

For Papers read at the Supplemental Meetings of Students, the Miller Scholarship to Mr. A. R. Sennett, and Miller Prizes to Messrs. P. C. Cowan, W. O. Rooper, R. Moreland (*tertius*), E. W. Cowan, and J. Fawcus.

The rules of the Council preclude awards being made to members of that body, but special thanks were voted to Mr. W. H. Preece, F.R.S., for his Paper on "Electrical Conductors."

The details of these awards are set forth in the Appendix to this Report.

SUBJECTS FOR PAPERS.

There has been recently issued a list of Subjects for Papers, together with a statement of the funds available for awarding premiums to the Authors of meritorious communications. This list has been circulated to every member of the Institution, wherever resident. The responsibility of the members, in upholding the reputation of the Institution as a depository of engineering information, is now greater than ever; and it is hoped that their efforts will be correspondingly increased so as to maintain the interest of the Minutes of Proceedings. This list of subjects is not to be regarded as limiting in the least degree the range of inquiry, nor is it to be taken in any sense as supplanting previous lists, but only as supplementing them, in the same way as this list itself will, in its turn, be altered, amended, and enlarged. The object in all cases is to convey an idea of the topics upon which information appears to be wanting. One direction in which it is thought members practising abroad may materially enrich the Proceedings is by furnishing detailed particulars of a technical character, respecting the engineering resources of newly-developed countries, embracing observations on preliminary exploration or pioneer-work, on the materials used, and on the tools and appliances available—such information, in fact, as a contractor would require when contemplating the execution of engineering works in those countries.

THE LIBRARY.

The Library has been efficiently maintained, so far as relates to procuring all the literature appertaining to engineering and the kindred sciences. But the question of accommodation is becoming a very serious one. The shelves are already overcrowded, and although some temporary alleviation has been obtained by the erection, during the recess, of additional cases in the top story of the building; if the present rate of increase continues—and the growth of the periodicals is proceeding at an accelerated pace—every available nook and corner will be occupied within the next three or four years; and then no further provision will be possible without encroaching upon the lights and passages, and materially interfering with the comfort and convenience of the members frequenting the premises.

It has been arranged to keep the Library open every night when meetings are held until their adjournment, whether the meetings are those of the Institution or of other societies to whom the use of the rooms is granted. In the Session 1884–85 there will be forty-two meetings of the Institution, including the Special Lectures on Thursdays and the Supplemental Meetings for Students on Fridays; and about twenty-eight meetings of other societies, as set forth in the card issued to the members at the commencement of the Session.

PRESENTS.

Among the presents received during the year were two which the Council records with much satisfaction. The late Mrs. Rendel bequeathed an oil painting by Carmichael, representing the Grimsby Docks, one of the chief works of her eminent husband, who was President of the Institution in 1852 and 1853; and from Lady Siemens was received a portrait of her late lamented husband, Sir William Siemens.

Many new members fulfil the engagement entered into on election by making a money donation to the Library Fund. The amount so received last year was £163 17*s*.

In reply to an application from the Smeaton Memorial Committee of Plymouth, asking for a copy of the bust of Smeaton, in the possession of the Institution, the Council had great pleasure in presenting a replica for the acceptance of the Committee.

LECTURES, SESSION 1884–85.

Arrangements have been made for the delivery, during the present session, of a course of six lectures on "The Theory and Practice of Hydromechanics." The titles of these lectures, with the names of the lecturers, are as under:—

"PHYSIOGRAPHY." By Mr. John Evans, V.P., & Treas. R.S., Assoc. Inst. C.E.
"WATER-SUPPLY." By Dr. William Pole, F.R.SS. L. and E., M. Inst. C.E.
"WATER-MOTORS." By Professor W. C. Unwin, B.Sc., M. Inst. C.E.
"INLAND NAVIGATIONS." By Sir Chas. A. Hartley, K.C.M.G., M. Inst. C.E.
"TIDES AND COAST-WORKS." By Sir John Coode, V.P., Inst. C.E.[1]
"FORM OF SHIPS." By Sir E. J. Reed, K.C.B., F.R.S., M. Inst. C.E., M.P.

CONCLUSION.

This brief statement it is trusted will be taken as evidence that the Council has zealously endeavoured to adopt every possible means for the advancement of the Institution, and so to transact its business as to confer the greatest benefits on the greatest number of members.

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[1] This was subsequently undertaken by Mr. Thomas Stevenson, M. Inst. C.E., owing to Sir John Coode having to leave for Australia.—SEC. INST. C.E.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.

£.		£.	s.	d.	£.	s.	d.	£.	s.	d.
	To balance in the hands of the Treasurer				1,083	15	5			
	" " Secretary				26	6	5	1,110	1	10
	INCOME:									
	— Subscriptions:—									
	Arrears	391	0	0						
	Current	11,584	3	6						
	Advance	84	11	0	12,059	14	6			
	— Library-Fund				163	17	0			
	— Minutes of Proceedings:—Repayment for Binding, &c. . .				264	2	3			
	— Publication-Fund				4	3	0			
	— Interest on Deposit-Account .				30	1	7			
	— Miscellaneous Receipts . .				1	1	6			
	— Dividends: 1 year on									
	Institution Investments.									
2,500	New Three per Cents. .	73	9	10						
500	Ditto (New purchase) .	14	13	4						
3,000	Caledonian Railway 4% Debenture Stock . .	117	10	0						
4,750	Great Eastern Ditto. .	186	0	10						
3,000	Great Northern Ditto .	117	10	0						
6,000	Great Western Ditto .	235	0	0						
3,000	Highland Ditto . . .	117	10	0						
3,000	Lancs. and Yorks. Ditto	117	10	0						
1,500	L. B. & S. C. Ditto . .	58	15	0						
6,000	L. & N. W. Ditto . .	235	0	0						
3,000	Midland Ditto . . .	117	10	0						
3,000	North Eastern Ditto .	117	10	0						
1,500	L. B. & S. C. 4½% Ditto	66	1	10						
3,000	Man. Shef. & L. Ditto .	132	3	8						
	6 months on									
250	Great Eastern 4% Ditto (New purchase) . .	4	17	11						
3,000	Lancs. & Yorks. Do. (do.)	58	15	0						
1,000	Great Eastern Do. (do.)	–	–	–						
£48,000	Total nominal or par value.				1,769	17	5	14,292	17	3
	Carried forward							£15,402	19	1

from the 1st DEC., 1883, *to the* 30th NOV., 1884.

EXPENDITURE.

Cr.

General Expenditure.

	£.	s.	d.	£.	s.	d.
By House and Establishment Charges:—						
Repairs, General	83	17	2			
Rent	644	12	10			
Rates and Taxes	389	10	9			
Rent of Telephone	23	13	0			
Insurance	43	14	0			
Fixtures and Furniture	230	7	10			
Lighting and Warming	101	16	3			
Tea and Coffee at Meetings	67	6	8			
Assistance at Meetings	29	13	6			
Household Expenses	133	12	0			
				1,748	4	0
— Postages, Telegrams, and Parcels	221	11	4			
— Stationery and Printing	590	5	2			
— Diplomas	96	14	4			
— Annual Dinner (Official Invitations, &c.)	240	19	3			
				1,149	10	1
— Salaries	1,900	0	0			
— Clerks, Messengers, and Housekeeper	743	0	0			
— Donation to late Housekeeper	30	0	0			
				2,673	0	0
— Library:—						
Books	222	3	8			
Periodicals	40	0	8			
Binding	156	15	6			
				418	19	10
— Publication:—						
"Minutes of Proceedings" (Vols. lxxv., lxxvi., lxxvii., and lxxviii.)	5,751	16	2			
Lectures on "Applications of Electricity"	441	19	3			
				6,193	15	5
— Lectures on Heat				213	15	7
— Legal Expenses				79	13	6
Carried forward				£12,476	18	5

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.

£.	s.	d.		£.	s.	d.	£.	s.	d.	£.	s.	d.
			Brought forward							15,402	19	1
			CAPITAL.									
			To Admission-Fees				2,970	9	0			
			— Life-Compositions				525	0	0	3,495	9	0
			TRUST-FUNDS.									
			To Dividends: 1 year on									
			Telford Fund.									
5,425	11	9	Three % Consols . .	159	7	8						
3,290	13	0	Three % Reduced (Unexpended Dividends)	96	11	4						
8,716	4	9	Total nominal or par value.				255	19	0			
			Manby Donation.									
250	0	0	Great Eastern Ry. Four % Debenture Stock.				9	15	10			
			Miller Fund.									
3,125	0	0	New Three per Cents.	91	15	8						
1,999	14	7	Three % Reduced (Unexpended Dividends)	58	16	10						
5,124	14	7	Total nominal or par value.				150	12	6			
			Howard Bequest.									
551	14	6	New Three per Cents.				16	3	10	432	11	2
										£19,330	19	3

SUMMARY OF INVESTMENTS.

	£.	s.	d.	£.	s.	d.
INSTITUTION-INVESTMENTS . . .				48,000	0	0
TRUST-FUNDS—						
Telford Fund	8,716	4	9			
Manby Donation	250	0	0			
Miller Fund	5,124	14	7			
Howard Bequest	551	14	6	14,642	13	10
				£62,642	13	10

from the 1st DEC., 1883, *to the* 30th NOV., 1884.

EXPENDITURE—*continued.*

Cr.

								£.	s.	d.
	Brought forward							12,476	18	5
	Capital-Investments.									
£.					£.	s.	d.			
By 500	New Three per Cents.				507	10	0			
— 1,250	Great Eastern Ry. Four % Debenture Stock				1,452	14	6			
— 3,000	Lancs. and Yorks. Ditto				3,361	19	2			
£4,750	Total nominal or par value.							5,322	3	8
	Trust-Funds.									
		£.	s.	d.						
	By Telford Premiums				284	3	9			
	— Manby Premium				23	2	0			
	— Miller Scholarship	40	0	0						
	— Miller Prizes	68	13	8						
					108	13	8			
	— Howard Quinquennial Prize				100	12	6			
								516	11	11
								18,315	14	0
	— Balance, Nov. 30, 1884, viz.:—									
	Cash in the hands of the Treasurer				1,014	12	11			
	„ „ Secretary				0	12	4			
								1,015	5	3
								£19,330	19	3

Examined with the Books and found correct.

(Signed) H. M. BRUNEL } *Auditors.*
E. BAZALGETTE }

JAMES FORREST, *Secretary,*
6th December, 1884.

PREMIUMS AWARDED.

SESSION 1884–85.

THE COUNCIL of The Institution of Civil Engineers have awarded the following Premiums:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1. A Watt Medal and a Telford Premium to Sydney Walker Barnaby, Assoc. M. Inst. C.E., for his Paper on "Hydraulic Propulsion."
2. A Telford Medal and a Telford Premium to Samuel Bagster Boulton, Assoc. Inst. C.E., for his Paper on "The Antiseptic Treatment of Timber."
3. A Telford Medal and a Telford Premium to William Foster, M.A., F.C.S., for his account of "Experiments on the Composition and Destructive Distillation of Coal."
4. A Telford Premium to William Tregarthen Douglass, Assoc. M. Inst. C.E., for his description of "The New Eddystone Lighthouse."
5. A Telford Premium to James Atkinson Longridge,[1] M. Inst. C.E., for his Paper on "Wire-gun Construction."
6. A Telford Premium to William Hackney,[2] B.Sc., Assoc. M. Inst. C.E., for his Paper on "The Adoption of Standard Forms of Test-pieces for Bars and Plates."
7. The Manby Premium to George Henry Stayton, Assoc. M. Inst. C.E., for his Paper on "Wood Pavement in the Metropolis."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1. A Telford Medal and a Telford Premium to Thomas Andrews, Assoc. M. Inst. C.E., F.R.S.E., for his Paper on "Galvanic Action between Wrought-iron, Cast Metals, and various Steels, during long exposure in Sea-water."

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[1] Has previously received a Telford medal and also a Watt medal.

[2] Has previously received a Telford medal.

2. A Telford Medal and a Telford Premium to Francis Collingwood, M. Inst. C.E., for his Paper "On Repairing the Cables of the Allegheny Suspension-Bridge at Pittsburgh, Pa., U.S.A."

3. A Telford Premium to James Henry Apjohn, M.A., M. Inst. C.E., for his note on "The Area of Sluice-opening necessary for the Supply-Sluice of a Tidal Canal."

4. A Telford Premium to Thomas Gillott, M. Inst. C.E., for his Paper "On the Basic, open-hearth, Steel Process."

5. A Telford Premium to James William Wyatt, Assoc. M. Inst. C.E., for his communication "On the Art of Paper-making by the Machine, as exemplified in the Manufacture of high-class Writings and Printings."

6. A Telford Premium to William Santo Crimp, Assoc. M. Inst. C.E., for his account of "The Wandle-Valley Main Drainage."

The special thanks of the Council were voted to their colleague Mr. W. H. Preece, for his Paper on "Electrical Conductors."

For Papers Read at the Supplemental Meetings of Students.

1. The Miller Scholarship to Alfred Richard Sennett,[1] Stud. Inst. C.E., for his Paper on "The Electric Light."

2. A Miller Prize to Peter Chalmers Cowan, Stud. Inst. C.E., for his notes on "The New York, West Shore, and Buffalo Railway, and the Methods used in its Construction."

3. A Miller Prize to Walter Osmond Rooper, Stud. Inst. C.E., for his account of "Emery Wheels, and Emery-wheel Machinery."

4. A Miller Prize to Richard Moreland (*tertius*), Stud. Inst. C.E., for his Paper on "Constructional Ironwork for Buildings."

5. A Miller Prize to Edward Woodrowe Cowan, Stud. Inst. C.E., and a Miller Prize to James Fawcus, Stud. Inst. C.E., for their joint Paper descriptive of "A Light-draught Launch."

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[1] Has since been elected an Assoc. M. Inst. C.E.

SUBJECTS FOR PAPERS.

SESSION 1884–85.

THE COUNCIL of The Institution of Civil Engineers invite Original Communications on any of the Subjects included in the following list, as well as on other analogous questions. For these, if approved, they will award Premiums, arising out of Special Funds bequeathed for the purpose, the particulars of which are as under :—

1. The TELFORD FUND, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces £250 annually.

2. The MANBY DONATION, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The MILLER FUND, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises £160 per annum. Out of this Fund the Council have established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and are prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years.

4. The HOWARD BEQUEST, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution." The annual income amounts to rather more than £16. It has been arranged to award this prize every five years, commencing from 1877. The next award will therefore be made in 1887.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the Premiums no distinction will be made between essays received from any one connected with the Institution (except in the cases of the Miller and the Howard bequests, which are limited by the donors), or from any other person, whether a Native or a Foreigner.

LIST.

1. Improved Instruments for Surveying and Levelling.
2. Machines and Measuring-Apparatus for testing Metals, and the Equipment generally of Mechanical Laboratories.
3. The Mechanical properties of Cold-Rolled Metal, as compared with Hot-Rolled Metal, and on the cold-rolling of iron shafting, as practised in America.
4. The effect produced on Steel by tempering in Oil and in Water.
5. The manufacture, strength and other properties of Castings of Malleable Cast Iron and Cast Steel.
6. The Thermic Properties of Metals commonly used in the Arts, especially with respect to Conductivity and Diathermancy at high temperatures.
7. The Manufacture of Steel-faced Armour-plates.
8. Ironfoundry-practice as regards Melting, with results obtained from various forms of cupola, pressures of blast, &c.
9. The various Systems of Brick-making by Machinery.
10. Gaseous Fuel, and the residual products of Gas-making.
11. The Manufacture of Artificial Fuel from Small Coal.
12. Steam-boiler Furnaces, with reference to Fuel-Consumption and to the Prevention of Smoke.
13. The principles to be observed in the laying out, construction, and equipment of Railways in new Countries.
14. The theoretical and practical effect of Gradients and of Curves on the Speed of Railway Trains.
15. The Application of the Compound Principle to Locomotive Engines.
16. Locomotive-Performances, with regard to Weight, Power, Fuel-Consumption, and Dynamometer-returns.

17. The comparative merits of Straight-Axles and of Crank-Axles for Locomotive Engines.

18. The Design and Construction of Locomotive- and Carriage-sheds on Railways.

19. Mechanical Power on Tramways, including Steam, Compressed-air, Electricity, Cables, &c.

20. The Principles involved in the Conservation or Improvement of any tidal River or Estuary.

21. Descriptions of recent Graving-docks, Gridirons and Floats.

22. Promenade- and other Piers; with reference to the effect of Sea-water on wrought- and cast-iron structures, and the best means of preserving the same.

23. The Modern Construction of Marine Engines.

24. On Built Crank-Shafts for Marine Engines, and on the liability of crank- and screw-shafts to fracture.

25. Vessels for Inland Navigation, with the mode of working them by stern-wheels, screws, &c.

26. The Methods of Removing Rock under Water.

27. Cranes and other Lifting-Machinery, employed either in the construction of large works, or for other purposes.

28. Dredging-Machinery for small Harbours, and for Drainage- and Irrigation-Canals.

29. The Ventilation of Sewers, with a summary of Experiments as to the motion, pressure, &c., of gas in sewers.

30. Filter-Presses for separating Fluid in Semi-fluids, particularly for the treatment of Sewage-Sludge.

31. Appliances for the rapid Shipment of Coals, with a comparison of different methods.

32. Winding-Machinery, Expansion-Gear, and Balancing-Apparatus, and the cost per ton of winding under different conditions and varying depths.

33. Under-ground Haulage, especially on the application of compressed air and of electrical power.

34. The Methods employed in securing large and irregular-shaped mineral workings.

35. Gold Quartz-crushing and amalgamating-appliances.

36. The Manufacture and Desilverization of Lead.

37. Electro-Motors; their theory, practical construction, efficiency, and power.

38. On Gearing for Dynamo-Machine Motors, and other high-speed machines.
39. The Transmission and Distribution of Electricity over large areas for lighting and for motive power, including Electric Railways, Hoists, &c.
40. Electrical-Measuring Instruments.
41. Submarine Telegraph-Cables, their manufacture, laying and repair, including deep-sea sounding.
42. Telpherage, or the automatic Electrical Transport of goods and passengers.
43. The Measurement of Work by Dynamometers, with descriptions of the apparatus.

INSTRUCTIONS FOR PREPARING COMMUNICATIONS.

The Essays should be written in the third person, and be legibly transcribed on foolscap paper, on one side only, leaving a margin on the left side, in order that the sheets may be bound. Every Paper must be prefaced by an Abstract not exceeding 1500 words in length.

Illustrations, when necessary, should be drawn on tracing-paper, to as small a scale as is consistent with distinctness, and ready to be engraved. When an illustrated communication is accepted for reading, a series of Diagrams will be required sufficiently large and boldly coloured to be clearly visible at a distance of 60 feet. These diagrams will be returned.

Papers which have been read at the Meetings of other Societies, or have been published, cannot be read at a Meeting of the Institution, nor be admitted in competition for the Premiums.

The Communications must be forwarded to the Secretary of the Institution, from whom any further information may be obtained. There is no specified date for the delivery of MSS., as when a Paper is not in time for one session it is dealt with in the succeeding one.

JAMES FORREST, *Secretary.*

THE INSTITUTION OF CIVIL ENGINEERS,
25, *Great George Street*, *Westminster*, *S.W.*
October 28, 1884.

EXCERPT BY-LAWS, SECTION XV., CLAUSE 3.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. Except as hereinbefore provided, no person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

NOTICE.

It has frequently occurred that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat, that the Institution as a body must not be considered responsible for the facts and opinions advanced in the Papers or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the inquiry; but that such notice, or award, must not be regarded as an expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

ORIGINAL COMMUNICATIONS

RECEIVED BETWEEN DECEMBER 1, 1883, AND NOVEMBER 30, 1884.

AUTHORS.

Allen, G. T. No. 1,971.—A Navigable Canal between the Damietta Branch of the Nile and the Bay of Suez.

Anderson, W. No. 1,987.—The Foundations of the Alexander II. Bridge over the Neva. With 1 Sheet of Illustrations. (Vol. lxxv., p. 286.)

————. No. 1,989.—Notes of a Journey through the N.-E. portion of the Delta of the Nile in April, 1884. (Vol. lxxvi., p. 346.)

Andrews, T. No. 1,985.—On Galvanic Action between Wrought-Iron, Cast Metals, and various Steels during long Exposure in Sea-water. (Vol. lxxvii., p. 323.)

Apjohn, J. H. No. 2,010.—On the Area of Sluice-Opening necessary for the Supply-Sluice of a Tidal Canal. With 7 Sheets of Illustrations. (Vol. lxxviii., p. 313.)

Barnaby, S. W. No. 1,968.—Hydraulic Propulsion. With 17 Diagrams. (Vol. lxxvii., p. 1.)

Bernays, J. No. 2,028.—Record of the Construction and Testing of some long Cast-iron Columns of H Section. With 1 Drawing and Table.

Birch, R. W. P. No. 1,972.—On the Passage of Upland-Water through a Tidal Estuary. With 3 Sheets of Illustrations. (Vol. lxxviii., p. 212.)

Bömches, F. No. 2,008.—The New Harbour of Trieste. With 5 Sheets of Illustrations. (Vol. lxxviii., p. 328.)

Boulton, S. B. No. 1,986.—On the Antiseptic Treatment of Timber. With 8 Diagrams. (Vol. lxxviii., p. 97.)

Brady, A. B. No. 2,026.—The Burnham Sewerage-works. With 3 Drawings and Specification. (*Post*, p. 35.)

Brebner, A., Jun. No. 2,002.—Lighthouse-Apparatus for Dipping-Lights. With 3 Sheets of Illustrations. (Vol. lxxviii., p. 361.)

Burge, C. O. No. 2,012.—The Comparative Value of Labour in different Countries. (Vol. lxxvii., p. 337.)

Clausius, Professor R. No. 1,976.—On the Theory of the Dynamo-Electric Machine. (Vol. lxxv., p. 247.)

Collingwood, F. No. 1,988.—On Repairing the Cables of the

AUTHORS.

Allegheny Suspension Bridge at Pittsburgh, U.S.A. (Vol. lxxvi., p. 334.)

Conder, F. R. No. 2,021.—Comparative Capacity of Modes of Transport. With 3 Drawings.

Crampton, J. No. 1,996. A System of Working the Kimberley Mine without removing the Reef. With 1 Drawing.

Crimp, W. S. No. 1966.—The Wandle-Valley Main Drainage. With Appendix and 2 Sheets of Illustrations. (Vol. lxxvi., p. 317.)

Cuningham, G. C. No. 1,995.—The Energy of Fuel in Locomotive Engines. With a Table.

Cunningham, D. No. 2,022.—Account of Shifting one of the Lighthouses at Buddonness, near Dundee Harbour. With 2 Photographs and a Plan. (*Post*, p. 347.)

Cuppari, G. No. 1,977.—On the Practical Results obtained from various Water-raising Machines in Holland. (Vol. lxxv., p. 261.)

Durand, —. No. 1,970.—Spontaneous Combustion in Collieries. (Vol. lxxv., p. 230.)

Foster, W. No. 1,980.—Experiments on the Composition and Destructive Distillation of Coal. (Vol. lxxvii., p. 162.)

Fowler, J. (of Stockton). No. 1,973.—Dredgers and Dredging on the Tees. (Vol. lxxv., p. 239.)

Ganga-Ram, L. No. 2,009.—"Mechanical Method of solving Engineering Formulas."

Gillott, T. No. 1,994.—The Basic, Open-Hearth, Steel-Process. With 2 sheets of Illustrations. (Vol. lxxvii., p. 297.)

Grantham, R. F. No. 2,037.—Works of Reclamation and their Maintenance, and a Description of the Reclamation of Brading Harbour. With 6 Drawings.

Guppy, T. R. No. 2,016. Pumping Machinery for Draining a portion of the Marshes near Fondi, Southern Italy. With 3 Maps. (*Post*, p. 307.)

Hagemann, G. A. No. 1,993.—Experiments on the Transmission of Heat. With 2 drawings. (Vol. lxxvii., p. 311.)

Hamilton-Smythe, A. J. No. 2,024.—A Comparison of British and Metric Measures for Engineering purposes.

Hassell, L. No. 2,017.—The New Zealand Surveys; with some Notes on the System.

————. No. 2,018.—Notes upon Snagging in the Wanganui River, Wellington, N.Z.

Hawgood, H. No. 2,040.—The Location of Railroads in the United States.

AUTHORS.

Hay, R. No. 1,978.—Strath Taieri Bridge, New Zealand. With 2 Tracings and 2 Photographs. (Vol. lxxvi., p. 330.)

Henderson, J. B. No. 2,033.—Seventeen Contract Drawings relating to the Gold Creek Reservoir, Brisbane Waterworks.[1]

Higgin, G. No. 2,015.—The Old Water-Supply of Seville. With 4 Sheets of Illustrations. (Vol. lxxviii., p. 334.)

Holt, P. W. M. No. 2,020.—Description of Survey of a Railway to connect the East and West Coasts of the Middle Island of New Zealand. With a Map and 12 Photographs.

Jackson, M. No. 1,999.—On Hauling out and Launching Vessels Sideways. (*Post*, p. 305.)

Jamieson, A. No. 2,029.—Electric Lighting for Steamships. With 12 sheets of Illustrations. (*Ante*, p. 1.)

Johnson, C. M. No. 2,014.—Water-Supply in some parts of Peru; and Dixon-Provands' Distilling Apparatus at Iquique. (Vol. lxxvii., p. 342.)

Kinder, C. W. No. 2,034.—Notes on Electric Blasting in China. With 3 Drawings, 4 Photographs, and a Sheet of Tables.

Kraft, J. No. 2,023.—Notes on Compressed-Air and Machinery for utilizing it. With small Drawings. (*Post*, p. 311.)

Langley, A. A. No. 2,045.—New Works at Lowestoft Harbour. With 7 Illustrations.

Mair, J. G. No. 2,038.—The Results of some Independent Engine-Tests. With Diagrams. (*Post*, p. 323.)

Marchant, F. W. No. 2,030.—The Tekapo Bridge, Mackenzie County, N.Z. With 2 Photographs. (*Post*, p. 355.)

——————. No. 2,031.—Notes on the Bearing-power of Piles.

Monson, E. No. 2,005.—The various Systems of Brickmaking by Machinery. With 46 Illustrations.

Morton, R. No. 2,003.—The System of Coaling at the Works of the late London Gaslight Company, Nine Elms. With 1 Sheet of Illustrations and 4 Photographs. (Vol. lxxviii., p. 357.)

Parsons, Hon. R. C. No. 1,990.—On the Working of Tramways by Steam. (*Ante*, p. 98.)

Pilbrow, J. No. 1,975.—Some particulars of an Artesian Well bored through the Oolitic Rocks at Bourn, Lincolnshire, in 1856. (Vol. lxxv., p. 245.)

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[1] Not reproduced in the Proceedings, but may be consulted in the Library.

AUTHORS.

Pilkington, W. No. 1,981.—On the Elevation, Storage, and Shipment of Grain. With 12 Drawings. (Vol. lxxvii., p. 237.)

Pole, W. No. 1,840 (Supplemental).—Further Data on Aerial Navigation.

Rich, W. E. No. 1,997.—On the Comparative Merits of Vertical and Horizontal Engines, and on Rotative Beam-Engines for Pumping. (Vol. lxxviii., p. 1.)

Roberts, T. No. 2,036.—Barmouth Waterworks. With 5 Sheets of Illustrations. (*Post*, p. 319.)

Robinson, G. No. 2,039.—Graving Dock at St. John's, Newfoundland. With Plans and Section.

Shellshear, W. No. 2,004. The Sydney Steam-Tramways. With 4 Sheets of Illustrations. (*Ante*, p. 120.)

Smart, D. S. No. 1,983.—The Modern Practice in the Construction of Steam-Boilers.

Stayton, G. H. No. 2,000.—Wood Pavement in the Metropolis. With 5 Sheets of Tables and 4 Sheets of Illustrations. (Vol. lxxviii., p. 240.)

Stroudley, W. No. 2,027.—The Construction of Locomotive Engines, and some results of their Working on the London, Brighton, and South Coast Railway.

Target, J. L. F. No. 2,013.—On the Progress of the Interoceanic Canal Works, Panama.

Thomas, J. H. No. 2,001.—Steep Gradients and Sharp Curves.

Thompson, A. M. No. 2,044.—The Signalling arrangements of the London and North-Western Railway.

Trotter, A. P. No. 1,964.—A Dioptric System of Uniform Distribution of Light. With 4 Sheets of Illustrations. (Vol. lxxviii., p. 346.)

Weeks, T. S. No. 2,041.—Torquay Waterworks. With 7 Diagrams, 2 Tables, and a Plan.

White, A. E. No. 1,974.—The Sewering of Towns on the Separate System. Size and Inclination of Sewers. (Vol. lxxviii., p. 366.)

Wright, B. F. No. 2,019.—Railways in Japan. Southern Section. With 5 Sheets of Illustrations.

Wyatt, J. W. No. 1,992.—The Art of Making Paper by the Machine, as exemplified in the Manufacture of high-class Writings and Printings. With 13 sheets of Illustrations. (*Post*, p. 251.)

Younger, T. B. No. 1,965. Foundations in British Guiana. With 1 Sheet of Illustrations.

LIST OF DONORS TO THE LIBRARY.

FROM DECEMBER 1, 1883, TO NOVEMBER 30, 1884.

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Abt, R.
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Adams, H.
Addenbrook, J. F.
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Agent-General of New South Wales.
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"Annales Industrielles."
Architekten und Ingenieur Verein für Böhmen.
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Association Amicale des Anciens Élèves de l'École Centrale.
Association des Ingénieurs sortis de l'École de Gand.
Association des Ingénieurs sortis de l'École de Liége.
Association of Engineering Societies.
Association of Municipal and Sanitary Engineers.
Athenæum.

B.

Baggallay, H. C.
Bailey, J. C.
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Baker, B.
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Bousfield, W. R.
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Bramall, H.
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Brearey, F. W.
Bright, E. B.
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Collegio degli Architetti ed Ingegneri in Genova.
Collegio degli Architetti ed Ingegneri in Milano.
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[1] Dr. William Pole having resigned his seat as a Member of Council, was subsequently elected Honorary Secretary.—SEC. INST. C.E.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 1992.*)

"The Art of making Paper by the Machine, as exemplified in the Manufacture of high-class Writings and Printings."

By JAMES WILLIAM WYATT, Assoc. M. Inst. C.E.

THE art of paper-making, if not the most important, is at least one of the most useful that has been invented. Paper has, in the present age of rapid advancement and improvement, acquired a degree of importance with which it would not have been credited a century ago. Being the vehicle of written thought between nations as well as individuals, it has contributed more to the advancement of the human race than any other material employed in the arts; and its manufacture constitutes an art depending more closely than any other upon the march of civilization. Its uses are now beyond number, and the demand for it so general that it has become an article of prime necessity, and one that is daily entering more and more largely into the ordinary wants and ordinary life of all classes.

The word "Paper" is derived from the Greek word πάπυρος, a rush which grew in the swamps on the banks of the Nile, about 10 to 12 feet high, and from which the Egyptians manufactured a writing material. The inner cuticles under the coarse exterior portion of the plant were carefully removed, and the thin leaves were laid side by side on a table, moistened with water, and rendered adhesive by the use of a paste made of very fine flour mixed with size or glue. Another layer was laid transversely on the top of the first, and the two were pressed together and dried in the sun, when they became sufficiently cemented to form a sheet. The sheet was then beaten smooth with a mallet, and a surface imparted to it by polishing with a piece of ivory or tooth.

This paper was probably known and used as far back as the third or fourth century B.C., and it continued in general use until the beginning of the sixth century of the present era, when it was superseded by parchment and the paper known as "Carta

Bombycina," made from cotton, which latter was then just being introduced from the East. From the Egyptians, the art of making paper from the papyrus was transmitted to the Romans, who greatly improved it, bestowing more care upon the various operations of washing, pressing, sizing, and smoothing, and they made many different kinds and qualities. The trade in papyrus became considerable, not only at Rome, but throughout the civilized world. The profits from the sale were so large that they produced a revenue sufficient for Firmus, who made himself master of Egypt towards the end of the third century, to boast that he had in his possession as much paper as could support his army. The papyrus, though it was submitted to a special process of manufacture, retained substantially its original form; and it is to the Chinese that the credit is due of having invented the art of making paper from pulp. They were familiar with the art about the beginning of the Christian era, the materials used being the bark of trees, parts of the bamboo cane, rice-straw, and cotton. The Arabians and Hindoos, by their inroads and conquests in Tartary at the close of the seventh century, learned the art from the Chinese. It was next introduced into Europe through Greece and Spain, the Arabs or Moors bringing it with them in their conquest of Spain during the eighth century, and the Greeks acquiring it through their commerce with Asia and Egypt. From Greece and Spain, the art was communicated to Germany, France, and Holland, and thence it reached England. Paper made from cotton, with authentic dates from the tenth and earlier centuries, is preserved, but linen fibre does not seem to have come into use until later, and cannot be traced back further than the middle of the fourteenth century.

The first account of the construction of a paper-mill of any note is the establishment of a large one at Nuremberg in 1390, by Ulman Stromer, a German, in which he employed a great number of persons for the manufacture of paper from linen and cotton fibre. A century afterwards a mill was erected in this country at Stevenage, in Hertfordshire, by Mr. John Tate, to which reference is made in a book printed by Caxton, about the year 1490. In 1588 John Spielman, a German, jeweller to Queen Elizabeth, owned a paper-mill near Dartford, for the erection of which he obtained from the Queen his knighthood, and a 10-year monopoly for the gathering of all rags, &c., necessary for the manufacture. Only very common paper, principally for wrapping purposes, was made there, the finer sorts coming always from France and Holland. About the year 1770, Whatman had the courage to examine, in the capacity of a workman, the continental mills. On his return to

England he founded the mill at Maidstone, which is known at the present day as the manufactory of the finest hand-made paper. Hitherto all paper had been made by hand, sheet by sheet. At the end of the eighteenth century, the idea of a machine, for producing in one operation a continuous web of paper from the prepared pulp, was conceived by a Frenchman named Robert. This machine, developed and rendered practicable in England, soon took up a place of first importance in the paper-trade; and from this time the manufacture was divided into two distinct branches, known respectively as hand-made and machine-made.

Early in the present century, Berthollet discovered the valuable bleaching properties of chlorine, which at once caused a revolution in the trade; manufacturers were able to produce white paper from materials that hitherto had been debarred from use for that purpose owing to their colour. About the year 1844, however, a sudden depreciation arose in the value of white papers, especially the French, due to the indiscriminate use of the bleaching agent. Paper-makers, although appreciating its value, were not aware of the necessity of destroying all traces of chlorine in the prepared pulp. This free chlorine gradually acting upon the fibres, injuriously affected their resisting power, and rendered the paper brittle and wanting in tenacity. Since that time the manufacture has steadily progressed.

Until the end of the eighteenth century, paper was made in Europe almost entirely from rags. At this period other substances were adopted as substitutes, due in part, no doubt, to the insufficient supply of rags, and consequent rise in price. The Author has a copy of a publication, printed by Burton, of London, and said to have been written by Matthias Koops; it was published in the year 1800, and is printed on the first paper made from straw in England. It was dedicated to the reigning sovereign, George III. An appendix is printed on paper made from wood fibre alone, which although hardly properly reduced, is strong, tough, and of a light yellow colour; the printing shows up well upon it, as also upon the straw-paper.

Paper has been made from a great variety of vegetable substances without the use of rags; in fact, almost any vegetable fibre can, by proper manipulation, be made into some sort of paper; but the principal substances which have a marketable value, and are used to any great extent, are esparto, wood, and straw.

MANUFACTURE OF MACHINE-MADE PAPER.

The different processes in the manufacture of machine-made paper are enumerated for treatment as under:—

1. *Materials.*—Linen; cotton, and esparto.

2. *Manufacture.*—Cutting and dusting; boiling; reducing to pulp, under the two heads: breaking, including bleaching and washing; beating. Producing from the prepared pulp a felted web by means of the paper-machine. Sizing, comprising animal and vegetable; glazing; finishing.

REMARKS ON THE ECONOMY OF A PAPER-MILL.

The Author's experience having hitherto been limited to the manufacture of the better classes of writing- and printing-papers, he proposes to give an account of the processes of manufacture as applied to those classes.

1. *Materials.*—One distinguishing feature in the manufacture of paper is that the materials for producing the finished article are either waste from other manufactories, or the private consumer, or substances for which little or no other use has been found, such as esparto fibre, the trade in which is about 190,000 tons per annum, representing in value over £1,200,000.

The main constituent in the structure of all plants is the vegetable fibre or cellulose, which forms the casing or walls of the different cells, being the woody portion of the plant, freed from all foreign substances, and it forms, so to speak, the skeleton of vegetable fibre to the amount of 75 to 78 per cent. Its forms and combinations are extremely varied, but it always consists of the same chemical elements, carbon, hydrogen, and oxygen, and in the same proportions.

Pure cellulose is composed of six parts by weight of carbon, ten of hydrogen, and five of oxygen, C_6, H_{10}, O_5; and this is confirmed by the analyses of different fibres.

Wagner[1] has found them for—

	Flax.	Cotton.	Wood.
C	43·63	43·30	43·87
H	6·21	6·40	6·23
O	50·16	50·30	49·90
	100·00	100·00	100·00

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[1] "Handbook of Chemical Technology," by Rudolf Wagner, Ph.D.; edited by Wm. Crookes, F.R.S. London, 1872.

The glutinous, resinous, siliceous and other intercellular matters surrounding the cells together constitute the perfect plant; and it is the object of the paper-maker to eliminate these impurities and to produce the fibre as pure and as strong as possible.

One indispensable condition which this organic substance ought to fulfil above all others, after having been subjected to the action of chemical agents for ridding it of foreign substances, is that it should remain in the form of filaments more or less elongated, and flexible enough to intertwine readily with one another.[1]

Flax, hemp, and cotton rags, having already undergone a process of manufacture, consist of almost pure fibres with the addition of fatty and colouring matters, which can be got rid of by simple boiling under a slight pressure of steam, and the use of an alkaline solution. But the substitutes, being used as they come from the soil, contain all the intercellular matter in its original form, and this has to be destroyed by a strong alkali under a high temperature. The vegetable fibre or cellulose, being of a tougher and stronger nature, is untouched by the action of caustic soda, unless carried too far; while other animal fibres and organic matters are rendered soluble or destroyed by it. The object of the paper-maker, in treating any one particular fibre, is to carry the action of the dissolving and bleaching agents just so far as to obtain the fibre as free from impurities, and as white in colour, as is necessary for the kind of paper he wishes to make from it. The usefulness of a plant for the manufacture of good white paper depends upon the strength and elasticity of its fibres; upon the proportion of cellular tissue contained in them; and upon the ease with which this can be freed from the incrusting and intercellular matters.[2]

A microscopical examination under a low power shows that different fibres are very differently formed. Figs. 1 (p. 256) represent the character of four of the principal fibres used in paper-making, namely linen, cotton, esparto, and wood.

The fibres of linen or flax consist of straight, elongated, cylindrical filaments or tubes, of from 0·157 inch to 2·598 inches in length, and 0·0006 inch to 0·00148 inch in diameter, with tapering extremities. These long fibres have very thick walls, formed of concentric layers of cellulose, endowed with a cohesion which is stronger on the surface than towards the inner walls more recently

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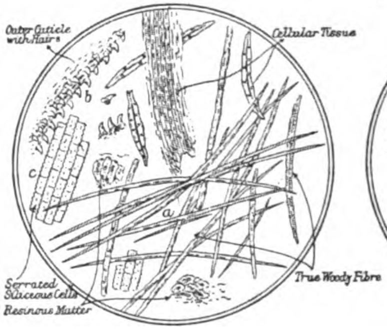
[1] "Succédanés des Chiffons," par M. A. Payen. Paris, 1881.

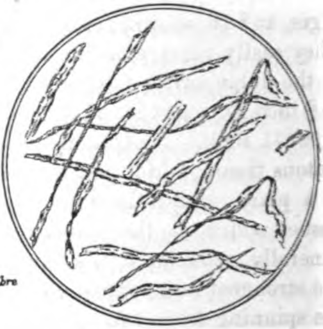
[2] For a fuller treatise on this complicated substance, see "Le Papier et ses Matières premières," par M. Orioli, read at the meeting of the Industrial Society of Mulhausen, 26th May, 1869.

Figs. 1.

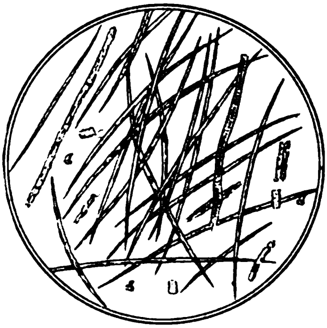
FIBRES EXAMINED MICROSCOPICALLY.


Outer Cuticle with Hairs
Cellular Tissue
b
c
a
Serrated Siliceous Cells
Resinous Matter
True Woody Fibre

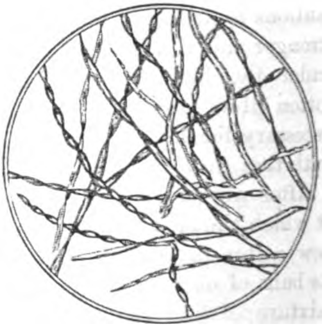
ESPARTO GRASS.
AFTER BOILING.



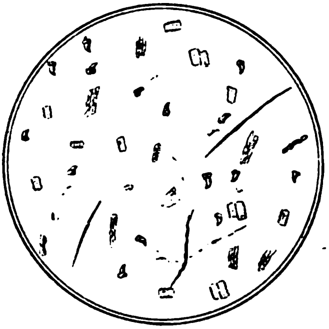
WOOD-PULP
CHEMICALLY PREPARED.



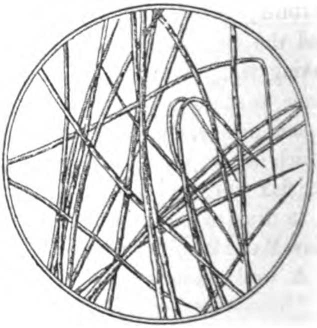
ESPARTO GRASS.
AFTER BREAKING, WASHING, & BLEACHING



COTTON FIBRES.



ESPARTO GRASS.
WASH-WATER.



FLAX FIBRES.

Magnified about 38 diameters.

secreted. They are stiff, tough and elastic, and do not bind or twist together.

The cotton fibres are of a close texture with very thin walls, and have the look of narrow, flat transparent tubes with thickened edges, and twisted several times upon themselves like a corkscrew. They easily bend and interlace one with the other. The length of the fibres varies from 1 to 1½ inch for long-stapled, and from ⅜ to ¾ inch for short-stapled; and their diameter is about 0·00043 to 0·00071 inch.[1] Cotton fibre is a development of the parenchymatous tissue, which is the weakest among the elementary organs of a plant, while the linen fibre is a development of the woody tissue, which is the strongest of such organs. It is, therefore, generally considered that linen only should be used for making the strongest and firmest paper. This may be the case as regards the spinning-fibre, but experience proves that it is by no means the rule in dealing with the bruised fibre for paper-making. With long and careful manipulation in the pulping engines, taking precautions to draw the fibre and not to cut it, new cotton will give a stronger and much closer paper than new linen. The linen fibre, under the beating-rolls, absorbs water more readily than the cotton fibre, and works up into a more "greasy" and wet state necessary for a stiff, firm sheet of finished paper, but it does not with that necessarily develop strength.

After numerous trials to obtain a strong machine-made paper, at which the Author was present, the strongest was produced with new cotton intimately mixed with about one-fifth or one-sixth of its bulk of new linen. As a rule all rag-papers are made with a mixture of linen and cotton, papers of different characters being obtained by varying the proportion of each. The linen fibre should be always slightly longer than the cotton to obtain a close even texture; unless this is done the sheet of paper will look "open," and the two fibres will not work in well with each other. On taking the nature of the two fibres into consideration this would seem to stand to reason; the straight stiff filaments of the linen would not easily mix and interlace with the longer cotton fibres, which latter, being of a flexible nature, twist more readily round the flax fibres as a nucleus.

In illustration of this, Mr. Orioli, in his article on Paper and its Raw Materials, before referred to, makes the following remarks:—

A well-made paper consists essentially of two portions; the one, formed principally by the stiffer pulps, is composed of long and tough fibres, which, in interlacing together, constitute the stoutness of the sheet of paper. They form, so to speak, the woof of the paper. If this portion of the fibres alone formed the sheet it would be irregular, cloudy, and without handle. It is necessary to intermix in the interstices of this woof, apparent even to the eye, much shorter fibres, in order to set off the finished sheet and render it thoroughly close. It is to the presence of these two kinds of fibres, mixed in the desired proportions, that the paper owes at once its bulk, its opacity, its homogeneity, its elasticity, in one word its good manufacture.

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[1] Spons' Encyclopædia of the Industrial Arts, Manufactures and Commercial Products, 1881, p. 959.

The esparto fibre consists of small fine tubes tapering to a point at both ends and very short, being finer and much shorter than those produced from rags. They occur in fibrovascular bundles through the stem of the plant surrounded by a mass of cellular tissue and resinous matter. Their length is from 0·019 inch to 0·137 inch, and their diameter varies from 0·00028 to 0·00072 inch. The true woody fibre takes different forms, the commonest being those marked *a*. They are all cylindrical tubes with thick walls, so thick at times that they become solid. The cellular tissue, being weaker and more easily acted upon by the strong alkali, is easily broken up and in great part washed away in the water from the breaking-engine. The inner surface of the grass is covered with a mass of short, pointed hairs, *b*. The peculiarly serrated cells *c* consist largely of silica; of these it is impossible to get rid of a certain portion, and they appear in the finished paper as transparent spots, especially under a high surface. If the wash-water from the breaking-engines is examined under the microscope, the contents are found to consist, not of true fibre, but of a mass of these siliceous cells, hairs, and small broken bits of cellular tissue.[1]

The peculiar value of this fibre, as contrasted with straw and other similar fibres, which much excel esparto in strength, stiffness and natural impermeability, is the ease with which it is bleached, producing a paper of great whiteness, non-transparent and, when animal-sized, comparing most favourably with that obtained from rags.

The fibres of wood are of a different appearance again. In utilizing wood as a material for paper-making, the primitive fibres or cellulose have to be freed from the woody incrustations which, during the course of vegetation, have gradually thickened, by concentric layers, the inner walls of these fibres. When this is done, they present the appearance of narrow flat ribands with thickened edges, and consist of thin open transparent membranes. The fibres are short and brittle, as compared with those before mentioned, and when used alone, impart their characteristics to the paper made from them, being too short and thick to yield that suppleness so characteristic of rag paper. The woods generally used are the firs and pines, although the pulp produced from the aspen and poplar is very good. Pine gives the strongest pulp, the white pitch pine being most suitable for fine papers. Scotch fir and other kinds of wood, more resinous or less white, yield a very good pulp but with less advantageous produce.

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[1] See an article by Ed. Bevan, published in the *British and Colonial Printer and Stationer*, entitled "The Microscopical Examination of Fibres." "Esparto." Aug. 1, 1881.

The raw materials used in almost all mills for the higher grades of paper are linen and cotton rags and the esparto fibre. The rags arrive at the mill from the different rag-merchants, either roughly sorted into grades or mixed in quality and material.

There is naturally a great variety of quality and character in the consignments of rags from different countries; and to one who is constantly handling them, it is easy in many cases to tell on examination the part from which they are collected. According to the climate, so is the clothing, heavier or lighter; some nations use more linen, some more cotton; while the collections from large towns are usually whiter and finer in quality than those from the country districts. The Russian supply is almost entirely linen, and that of a very strong and fine quality, although coarsely spun and low in colour. The bulk of the French and Dutch supply is cotton; while in Germany linen has the preponderance. The quality of the new linen and cotton cuttings from Great Britain is much superior to that from abroad—finer, purer, and less adulterated; but the supply of used rags, such as it is, is principally of a low quality, presumably because it is procured from the lowest classes of the population, who alone realise the necessity of turning every penny to account. The French cottons are characterised by their want of bulk and flimsy nature, when new being filled with starch and loading.

Esparto grass (*Stipa Tenacissima* or *Machrochloa Tenacissima*)—so called in Spain, and *Alfa* in Africa, is a spontaneous product of the siliceous and ferruginous soils of Southern and Eastern Spain and North Africa. It is a coarse strong grass growing in rush-like tufts, from 2 to 10 feet in circumference. It is not harvested by mowing, but during summer and autumn in dry weather is pulled by hand from the stems, the roots being left in the ground. The leaves grow to a length of from 6 inches to 3 feet, and are rather flat during growth, becoming dry and curled up at maturity. The leaf is gathered shortly before maturity; if allowed to mature, as is the case when used for making ropes, mats, or carpets, the silica and iron contained in it are more closely combined, and, in consequence, necessitate longer and more costly boiling and bleaching; if, on the other hand, it is gathered too green, the fibres being more or less transparent, would afford a sort of vegetable paper. Lands near the sea coast, at a moderate altitude, exposed to the sun and dry, are most favourable for its growth. Near the coast it is usually shorter and more discoloured, but finer and more tenacious than in the interior, where it is long, thick, and of a brighter colour.

There is a great difference between the two kinds in their behaviour in the mill. The Spanish crop, although shorter, more twisted and less handsome in appearance, is much more easily boiled, with less alkali, and bleaches to a brilliant white. The African crop, on the contrary, which looks greener and straighter, as if not sufficiently matured, wastes much more through the various operations, does not come up in colour, and gives a weaker paper. The Author has seen fine and strong thin bank paper made entirely from the best Spanish esparto.

The following comparison of the value, as a paper-making material, on the one hand of rags, a fibre already manufactured and prepared, and on the other of the esparto grass, an unprepared natural product, may be of interest. Esparto, during the various processes of manufacture, suffers a total loss of about 48·2 per cent., while the average loss on all grades of linen and cotton rags is about 27 per cent.; and the relative value of the two as a manufacturing material is represented by the proportion, 52 to 73. A very different result is obtained, however, if flax and cotton from the raw material be compared with the manufactured paper in the same manner as esparto. Esparto loses about 40 per cent. of its weight in drying, so that 100 lbs. of raw esparto produce about 31·06 lbs. of paper. Out of 100 lbs. of raw picked flax 56 lbs. of retted flax are obtained. From this amount only 9 lbs. of finished yarn are produced. This is again diminished in bleaching to 6·75 lbs. of bleached linen yarn. A further loss of about 25 per cent. in converting into paper reduces the quantity of paper obtained from 100 lbs. of raw flax to only about 5 lbs. Cotton furnishes a better result; 100 lbs. of raw picked seedcotton produces, after ginning to get rid of the seeds, 33·4 lbs. of ginned cotton. From this 29·4 lbs. of white cotton yarn are obtained. There is an additional loss of about 20 per cent. in manufacturing into paper, giving 23·6 lbs. of paper per 100 lbs. of raw cotton.[1]

2. *Manufacture.*—The paper-maker sorts the rags into grades to suit the paper he manufactures. As a general rule, the classes are ranged under the following heads:—linen and cotton; used and unused; bleached and unbleached; old and new colours and prints; blues, &c. These are again subdivided, according to their strength and cleanliness.

The rags, as received at the manufactory, contain sand, dust, and other impurities, which must be separated before passing them on to the boiler, besides their being sorted and cut. They are usually first passed in bulk through an ordinary revolving duster, where they are freed from most of the adhering dust. There are various forms of dusters and thrashers. A good and simple form for preliminary operations consists merely of a square frame, covered with ¼-inch wire mesh, revolving on a shaft at a slight incline, and enclosed in a wooden box. The rags travel gradually down the duster, getting well tossed; the light dust is carried up a shaft by a revolving fan, and the heavy particles fall through the meshes into the lower part of the box.

A rag-duster, for giving a final dusting to cut-rags before passing them on to the mill, is represented in Plate 6. It consists of a circular body covered with ¼-inch mesh, similar to the square one before described. Lengthways inside the duster planks on end give the rags a good tossing as they revolve; they are so sloped as, at the same time, to push them forward towards the mouth. Before the duster is a rapidly-revolving double "willow," which by its violent action disentangles from the rag all remaining dust and particles. By a suitable mechanical arrangement, the willow is furnished at intervals with a travelling felt carrying the rags, a door being at the same time let down before the mouth of the willow. This allows the rags to receive a good tossing in the willow, and they pass at once into the duster when the door is lifted.

The unsorted rags have to be sorted into the different grades; and all have to be cut to a workable size. The best size is about

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[1] "Cotton" and "Flax," in Encyclopædia Britannica. Ninth edition.

4 inches square, anything much larger than this not working well under the rolls, either passing through too quickly, or rolling up into lumps. Smaller sizes occasion waste of fibre.

The sorting and cutting are done by women standing before square tables covered with coarse wire-cloth of ¼-inch mesh, and surrounded by enough baskets or bags to provide one for every grade of rag sorted. The cutting-tables are about 3 feet square, the upper surface being composed of wire-cloth, whilst underneath there is a drawer. A scythe-shaped knife is firmly fixed in a nearly upright position in the centre of the table, with the back towards the worker. The woman cuts the rags by handfuls, and, at the same time, separates from them all buttons, leather, india-rubber, and other foreign substances, as well as small pieces of rag of different qualities overlooked by the sorter. The cut rags should all pass in review on large tables before overseers, as a check on the work of the cutters. Hand-cutting is expensive work, and machines have been designed to perform the same; but, except perhaps for the lowest grades of materials such as ropes, they are in every way inferior. Unless kept very sharp, they are found rather to tear than to cut the rag, thus causing a waste of fibre. Such machines, too, cannot perform the work of selection, or the removal of impurities from the material, which can only be done by close and careful examination at the time of cutting.

All rags contain a small percentage of inherent moisture, varying, according to the fineness of the rag, from 3 to 6 per cent.; it should not be more. The waste occasioned by the dusting, sorting, and cutting, increases with the coarseness and oldness of the material. That in the preliminary dusting and sorting is about 0·4 to 2·0 per cent., and mounts up to even 5 per cent. for very old, coarse and much-worn rags. The waste in the cutting and final dusting varies from 1·0 to 1·3 per cent. for fine new cottons; 2·0 to 4·0 per cent. for coarse white cottons; 1·5 to 2·5 per cent. for fine white linens; 2·5 to 3·0 per cent. for coarse linens; and 4 per cent. and higher for the lower grades. Summing up these results, the following is the total waste of rags from sorting, cutting, and dusting, together with their natural moisture:—4 to 7 per cent. for fine new cottons; 8 to 10 per cent. for coarse white cottons; 5 to 8 per cent. for fine linens; 9 to 12 per cent. for coarse linens; and 14 to 16 per cent. and upwards for the lower grades.

The esparto arrives packed in bales from the harvest-fields in Spain and Africa, and is usually overhauled by women before boiling, who pick out all roots, pieces of heather, &c., that have got mixed with the grass. It is then passed through an ordinary thrashing-machine to free it from dust and sand, and is ready for the boiler.

The process of boiling cleans the rag, destroys the fatty, colouring and other deleterious and extraneous matter surrounding the fibre, and softens the material by decomposing a substance which Prouteaux has called vegetable gluten,[1] and which renders the fibre too stiff to be readily made into paper. These effects are produced by boiling with an alkaline solution under a moderate steam-pressure. The natural products surrounding the fibres in the raw material having already been eliminated in the cotton- and flax-mills, a mere cleansing process suffices to render the fibres fit for conversion into paper.

In former times a peculiar process of fermentation called "rotting" took the place of boiling. The rags were wetted and laid in heaps for a certain length of time, during which fermentation was set up, manifested by the increased temperature of the mass, and by the appearance of a vegetable mould. This method, unprofitable in every way, both as regards waste of time and material, was soon superseded by the boiling process.

Boilers used for cleansing the rags are either rotary or stationary. The advantages claimed for the rotary are—greater uniformity in the boiling, the alkaline ley being able better to intermix thoroughly with the rags owing to the rotary motion; and the more convenient emptying of the boiled rags through a door in the bottom, whereas in the stationary boiler, the lifting of the rags through the door in the top is hard and disagreeable work. The first advantage seems a doubtful one, as there can be no blow-off while the rotary-boiler is in motion, and the same circulation through the material seems to be effected by the entrance of steam at the bottom of the stationary-boiler and its escape at the top; thus having to force its way through the whole mass of rags. That this does occur, and thoroughly, is shown by the fact that frequently fibres and occasionably even small pieces of rag are blown up into the condensing-tank.

The rotary-boiler consists of a wrought-iron cylinder, from 10 to 25 feet long, and about 7 feet in diameter; or more usually it is spherical, about 8 feet in diameter. It is suspended horizontally, and revolves on trunnions driven by gearing. All the working parts must be strong and solid, owing to the great weight of the revolving parts. The steam enters through a stuffing-box in the trunnions.

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[1] "Guide Pratique de la Fabrication du Papier et du Carton." Par A. Prouteaux. Paris 1864.

A simple and efficient form of stationary-boiler is shown in Plate 6. It is dome-shaped, furnished with a steam-pipe passing through the top, down the centre and terminating at the bottom in four or five D-shaped pipes, through which the steam escapes, and forces itself upwards through the rags. Over these pipes and the bottom of the boiler a false bottom of perforated plates is laid to let the water drain off. The blow-off steam can be condensed in a tank of water, which being heated can then be used as feed-water for the lower classes of rags or grass. There must be sufficient water to cover all the rags. After the water and ley from the boiling have been run off, the boiler is filled two or three times with cold water, which is at once run off, to clean the rags. Some of the lowest grades, owing to the amount of alkaline ley used, require a second boiling with water alone, after the first water has been run off. A boiler, such as shown in Plate 6, will take from 12 to 18 cwt. of rags. Steam-pressure of 10 lbs. per square inch is sufficient to boil most rags, and this is economically obtained in a large mill from the back-pressure steam from all the high-pressure workings. The number of hours' boiling depends entirely on the quality of the rag. Cottons need from four to eight hours, and linens from eight to twelve hours.

There are various opinions as regards the kind of alkaline ley to be used. Some manufacturers prefer lime, some soda, and others an alkaline mixture of the two. Pure caustic soda in solution seems to be too strong and violent in action for any except the lowest grades. A causticized solution of soda, produced by the intermixture of carbonate of soda or soda ash with an excess of slaked lime, boiled together, has answered admirably for most grades of rags, a greater or less quantity of the mixture being used according to the quality of the material. A ton of quick-lime slaked and boiled together with 660 lbs. of soda ash, with a sufficient quantity of water to bring the solution to a specific gravity of about 1·06 (12° Twaddell), and taken off in three draughts, supplies a satisfactory mixture. Cotton rags will take seven to eighteen gallons of this mixture to the cwt., and linen fifteen to thirty-five gallons.

In order to reduce esparto fibre from its raw state into a fit condition for manufacture, it has to be freed from all incrusting and intercellular matter. To effect this it is digested with a strong solution of caustic soda under a high temperature. A good form of boiler for esparto (Plate 6), known as Rœckner's Patent, is charged at the top, and the boiled material taken out from a door at the side. The curved pipe at the side, called the "vomiter," is supposed to ensure a thorough circulation of steam and ley through the whole mass. The steam, as well as entering below, is carried in at the top of the boiler, where it issues downwards from a circular pipe through a number of small holes. A depth of 3 or 4 feet of water and the caustic solution are first put in, and brought to the boiling point before charging, or the grass would not be digested rapidly enough to fill the boiler. The pressure is kept at from 35 to 40 lbs. per square inch for the best quality of grass, for three to four hours, during half of which time the maximum pressure is maintained, and is eased off towards the end of the boiling. The strong caustic ley is then run off to a tank, from whence the soda is recovered in the form of black ash. The grass, though very dark in colour, should now be fully digested, soft and short, and it is subjected to a second boil with plain water for about an hour, with a steam-pressure of 12 to 15 lbs. per square inch to wash out the remains of the caustic solution. The boiler is then filled and emptied two or three times with cold water, to thoroughly wash the material and cool the boiler, when the grass is ready.

The above is merely a record of the boiling operation in one particular mill. The steam pressure, amount of ley, &c., varies, of course, in almost every mill. Improvements are now being introduced, and have been adopted in some mills in the boiling, but more especially in the subsequent washing.

The caustic solution is obtained by simply dissolving the crystallized hydrate of soda, $NaHO$, in boiling water, and allowing the solution to settle. From 15 to 20 lbs. of soda are required to digest 1 cwt. of grass.

It is as well to overhaul the grass in the wet state after boiling to ensure all roots being picked out, as they retain their dark colour and are then more easily seen. This picking occupies a number of hands. As a measure of economy and for more effectively cleansing the material, an ingenious machine, which does away with the necessity of overhauling the grass by hand, has been devised. It is similar to, and on the same principle as, the paper-making machine. By means of this machine, the grass, after being opened out in the breaking-engine, is allowed to flow over a long settling table, where all the heavy impurities fall to the bottom. It is next strained through coarse-cut strainer-plates, and flows over a short wire and through a pair of press-rolls, and leaves the machine with about 50 per cent. of moisture, ready for furnishing to the beating-engine. The loss of the different materials during the process of boiling will be found in the Table in the Appendix, showing the individual and total loss after each operation.

The process of reducing any fibre to a pulp embraces four important operations, namely, washing, breaking, bleaching, and beating. For most classes of papers these four operations are performed in two engines, known respectively as the breaking-engine and the beating-engine. The first three operations of washing, breaking and bleaching, take place in the breaker; the beater being reserved for reducing the pulp to a workable state, "making the paper" as it is called.

The object to be attained in this process, the most important and delicate in the whole manufacture, is simply to produce the fibre in such a pure and finely-divided state as will render it most easily available for making a close, homogeneous, and strong felted web on the paper-machine.

It is necessary clearly to understand the difference between the results to be attained in the two principal operations of this process, namely that of breaking and that of beating. First, as regards rags, these being of a textile nature and the fibres interwoven, require to be drawn out from one another and opened up to allow the water and bleaching agent to act on each individual fibre. This, then, is the object of the breaker—to destroy the identity of the material as rag, and yet to retain the fibre as long as possible; to draw the fibres gradually from the piece or to teaze it out, until none of the original texture is left. The object of the beater is to reduce these fibres to a length suitable for the class of paper to be made from them, and also, by causing them to absorb and carry the water, to beat them into a stiff pulp of sufficient consistency for the paper to be made, and for the requirements of the paper-making machine.

As regards esparto grass, the objects to be attained and the mode of obtaining them, although producing the same result, are very different. The esparto fibre differs much from either linen or cotton, being extremely short, in fact short enough for making paper originally; and being also in the condition of natural fibre not woven into cloth, it only need be broken up and disintegrated. To compensate for the shortness and fineness of the fibres, they require strong beating into a stiff wet pulp to produce a firm and close sheet of paper. Were it not for the necessity of washing and bleaching the material, both the operations of breaking and beating might be performed in one engine, but it is undesirable for high-class papers to introduce into the beater chemicals other than those wanted in the finished paper.

Before the present pulping-engines were invented, rags were reduced to their original fibres by pounding under heavy hammers or stampers. The rags were placed in wooden vats, in which close-fitting mallets were moved up and down by water-power through the medium of levers. A stream of water, supplied from the top and flowing away through a grating in the bottom, kept up a continual washing. The pounding lasted from twelve to twenty hours, until a thorough disintegration and transformation of the rags into pulp had taken place. This process was good in principle, ensured the fibres being retained of full length, prevented any cutting action, and produced strong paper; still, at best, the stuff must have been very unequal and half-cleared. It was a lengthy and cumbersome process, and soon gave way on the advent of the "Holländer." The honour of this invention belongs to the Dutch, who, on account of the insufficiency of their motive-power, the wind, to work heavy stampers, were led to the discovery of cylinders provided with blades to tear the rags. This engine, improved greatly since its introduction a century ago, is now in use in every paper-mill in one form or another. For the lowest classes of papers, such as wrappings, the whole process takes place in one engine; but it does not answer for higher classes, as the rolls and bars, while suitable for opening the material, are not suitable for reducing it to a fine pulp.

In some mills the bleaching is done in a separate engine, known as the "intermediate," or "poacher," the duty of which is either simply to turn the stuff round during bleaching and then to wash it, or else it is furnished with roll and plate to assist the beater. The idea is, that the acids and bleaching agent act on the iron of the engine, bars and plate, causing rust, and the intermediate is therefore made or lined with an acid-proof material such as stone or lead. This idea, although a right one, when put into practice does not compensate in its advantages for the increased space and plant required in the mill; and similar results can be obtained by lining all the exposed ironwork of the breakers with lead, except, of course, the bars of the roll and plate. In mills where the finest classes of writings are manufactured, it is better to have both breaking- and beating-engines, and all the water-pipes lined with lead, to prevent the iron rusting and coming away as spots in the paper. When it is considered that a single speck or spot in a sheet of high-class paper is sufficient to condemn it as perfect paper, and to reduce its value by 10 per cent., it will be readily understood how all-important cleanliness is in every shape and form throughout the manufacture.

It has been the practice in a good many mills to run the "half-stuff," as the pulp is called when it leaves the breaker, broken in and bleached, into stone cisterns or vats fitted with perforated bottoms, the drainage through which could be opened or closed. The half-stuff lay in "steep" in these vats for some hours, to allow the chlorine to have full effect. It was then drained off, the remaining liquor was pressed out by a hydraulic press, and the half-stuff was ready to be furnished into the beaters. This process occasions a waste of time, increased labour, space, and plant in the mill, and also a slight loss of material while draining. It has been found that the colour obtained in the engine direct, is equal to that of stuff that has lain some hours in the steeps, without an increased expenditure of bleaching liquor. What is known as the "direct system," is now coming into frequent use. In this system (Plate 6) the breakers are raised on a platform above the beaters, so as to allow the "half-stuff" when ready to flow down a pipe into the beaters. The superfluous bleach-liquor is got rid of as far as possible by a revolving drum-washer on the breaker.

There are numerous forms of pulping-engines, but the original and most common form is that of an oblong shallow vessel, with circular ends, divided along the centre by a partition or "mid-feather," extending as far as the rectangular part. Across the centre of one half and flush with the bottom of the engine, is fixed the "plate," consisting of a number of parallel steel bars securely bedded in a wooden frame. Above this plate revolves a cylinder, technically called "the roll," round the circumference of which bars of steel are firmly fastened, parallel to the axis or shaft, in bunches or clumps of two together in the breaker, and three in the beater. By the revolutions of the roll upon the bars of the plate the rags are transformed into pulp. The roll can be raised or lowered on the plate by an elevator or lifter, so as to increase or diminish as desired the cutting action of the bars and plate on the material. In front of the roll, the bottom of the engine has a slight slope up to the level of the plate. Behind the roll, it follows the curve of the circumference to a little below the centre of its axis, when it falls gradually back to the original level. This is called the "backfall," because the rags or pulp fall down this slope back into the engine from the buckets of the roll. The duty of the roll is twofold, namely, to tear and cut the material to reduce it to a pulp, and also to act as a lifter or pump to cause the stuff to circulate round the engine. Its action is exactly the reverse of an undershot water-wheel, the space between the bars acting as buckets for lifting the stuff, and discharging it again over the backfall, and it is the only means of circulation.

These engines were formerly made of strong wood, and lined inside with lead or copper; but for many years they have been successfully cast in iron, all in one piece, including the partition or midfeather. For the higher grades of papers, both engines are best lined with lead for the reason before mentioned. For papers used for photographic purposes, in which absolute freedom from iron is required, and in the manufacture of which the raw material is never allowed to come in contact with it, the engines are constructed of stone and lined internally with glazed tiles set flush in cement.

Plans and sections of a good type of engine, constructed by Messrs. George and William Bertram, of Edinburgh, are given in Plate 6; and the details hereinafter mentioned are those suitable for such engines, of a size to turn out from 200 to 250 lbs. of finished paper. The rolls were formerly made of solid wood, preferably of elm; but the use of cast iron has now superseded it. They should be of about 1½ ton to 2 tons weight, the breaker being the heavier. A heavy roll is preferable to a light one, as it is surer in its action, and less liable to spring out of its bearings under extra heavy work.

The bars are sunk and wedged in grooves cast in the periphery of the roll. The best and most effective arrangement of the bars in the roll is to fix them in sets or clumps, and not to space them out equally over the circumference, as they then do not seem to beat so well and thoroughly as when acting together in clumps, although giving the same number of cuts per minute; neither does the stuff travel so well.

The plate on which the roll travels, has to bear its full weight, and the greater part of the work done on the material. It must, therefore, be substantial, strong, and of good material. The steel bars or knives are bolted together and accurately fitted to form a segment of the same circle as the roll; they are fixed in a wooden frame, which lies in a box cast in the bottom of the engine below the roll, and from which it can be easily withdrawn for re-sharpening. The bars of the plate must of course be set at an angle to the fly-bars of the roll, to act as shears in the same manner as a pair of scissors. The greater this angle, the greater will be the cutting action on the material. In the engines in question the angle between the plate and the fly-bars is about 3°. Were the bars of the plate made straight the stuff would have a tendency to travel up to the forward end of the plate, and the work would be unequal. To remedy this the bars are bent in the centre, forming an elbow. The number of bars in the plate varies from ten to twenty-four, and their pitch from ¼ inch to ¾ inch. To treat rags and strong material satisfactorily it does not answer to have the bars too close together, otherwise the material is drawn through with little effect, and needs too long a time in the engine before being ready, and it is then so "greasy" and "wet," as to be unsuitable for working on the machine. Experiments conducted in a well-known mill in the south of England showed that the best results were obtained in working rags with a pitch of about ⅝ inch for the breakers, giving twelve bars in a plate, and ½ inch for the beaters, giving fifteen bars to the plate. The bars should not be less than ¼ inch thick, and, to obtain the required pitch, they are separated from one another by dividers; these are of zinc in the beater, and of brass in the breakers, to avoid corrosion under the action of the strong chemicals.

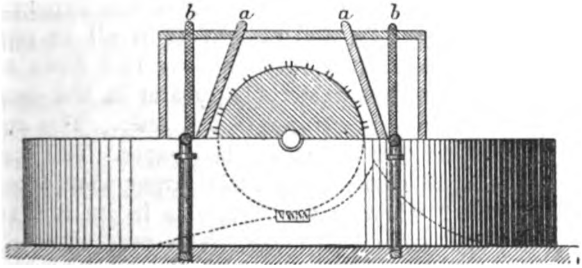
As regards the manipulation of esparto, the fibre is so short and so easily subdivided, that the number and pitch of the bars seems to be of less moment. The Author knows of two mills both working esparto papers, and both turning out a good article; one has twelve bars in the breaker and fifteen in the beater, and the other sixteen in the former and twenty-two in the latter. But as far as the Author's experience goes, he inclines to the opinion that the smaller number of bars produces the best results, opening out the material more easily and quickly, and producing a pulp more workable on the machine.

Plates of brass are sometimes adopted in the beater. Being of a softer material, the action of the knives is less violent and rough on the pulp, and produces a less harsh and more uniform pulp. But the stuff needs longer beating in the engine, and is more liable to become greasy and wet, requiring a lower speed on the making-machine. Where fineness of texture is a desideratum rather than increased output, brass plates might be used to advantage. In some papers, such as photographic paper, where all trace of rust or iron in any form must be excluded, and the paper at the same time uniform in texture, the bars of both roll and plate are made of brass, or of a composition that will not rust.

The speed of the beater-roll is usually about thirty to forty revolutions more per minute than that of the breaker. The work to be done is not nearly so violent; the number of bars in roll and plate is therefore increased, the speed of the roll quickened, and its weight diminished. As a better beaten pulp is produced in a shorter time by a roll revolving quickly than slowly, the number of revolutions have been much increased. From a speed of one hundred and thirty revolutions, or about 1,200 feet per minute for the breaker-roll, and of one hundred and seventy revolutions or 1,550 feet per minute for the beater-roll, the speeds are now increased to as much as one hundred and sixty revolutions, or 1,500 feet per minute for the former, and two hundred revolutions, or 1,800 feet per minute for the latter. These high speeds give the enormous number of 82,800 cuts per minute in the breaker, and 207,000 in the beater.

The rags contain a quantity of sand, dirt, and other small impurities, closely mixed with the fibres, and which cannot be entirely separated from them until they have been opened out under the action of the roll. The small and light particles float on the surface and are borne away with the dirty water; the heavier ones fall to the bottom of the engine, and are conveyed away through a sand-trap consisting of a perforated grating covering a hollow channel cast in the bottom of the engine, and connected with a plug-cock. This trap is situated on the rising slope in front of the roll, where there is the least chance of the water used for washing the half-stuff into the beater disturbing its contents and carrying them down with the stuff.

FIG. 2.



The rolls of the engines are always encased in a wooden cover to prevent the stuff flying about the place. The cover of the washing engine used to have four slits or grooves cut down through the top, two on each side of the roll, Fig. 2. The two slits, *a*, next the cylinder were made for boards of wood to slide on grooves cut in the inside of the cover. These were put in at the commencement, and removed at the close of the washing process.

The other two slits, *b*, contained two frames of very fine copper wire-cloth of about 66 meshes to the inch. The washing process was formerly carried on by the rags or pulp being driven violently upon the wire-cloth frames referred to, by the rapid revolution of the roll; the dirty water flowed away through a pipe down the side of the engine. This plan has been improved upon by the use of a circular drum-washer revolving in the stuff and driven by a belt from the roll-shaft (Plate 6). It is simply a drum covered with fine wire-gauze. Round its shaft is fixed a hollow cone sloping towards the centre of the engine, and at equal intervals on this cone, buckets are fixed which dip into the stuff, discharging their contents down the cone, and through an opening cast in the mid-feather, and connected with a waste-pipe below. This washer is furnished with lifting gear. The beater requires neither washers nor sandtrap, and consequently a much less complex arrangement of discharge-passages and pipes.

Engines are made to hold almost any quantity of paper from 150 lbs. to upwards of 1,000 lbs. of dry pulp. In a mill where one quality, or no great variety, of material is used, and where the machines can run on one class and weight of paper for a long period, a large engine would be an advantage, needing less power, labour, and plant. But where the outturn consists of many qualities and weights, entailing a great variety of material, where the orders are small and various, and the different materials mixed in one paper, smaller engines are a decided advantage, and the economy of the making department is more easily carried on. In working high-classed and expensive papers less supervision and care can be bestowed on the pulp if it is all in one engine instead of being distributed between four and five; and in a large engine the loss is considerably greater in the case of any mischance or accident happening to the pulp. The engines in question hold about 250 lbs. of finished paper. The contents of the breaker must of course be a little larger than those of the beater, as the stuff when in the former is in its raw state, and therefore requires more free space. The proportion should be about 5 to 4.

As soon as the breaker is filled with water, the rags are gradually admitted into the engine before the roll by hand. The roll should never be lowered more than is just necessary to draw the material into fibre, all cutting action being left to the beater. The process of reducing the rags to half-stuff takes from two to four hours, or more, depending partly on the material, but principally on the thickness of paper to be made from it. For thin papers the fibres must be long and very gradually drawn out to obtain the full strength of the material to compensate for their scarcity in the sheet. For the first half-hour or so the roll is raised off the plate, and the rags allowed to wash alone. The sand-trap is open, and most of the sand and heavy impurities left in the rag escape that way. As soon as the water begins to run clear, the sand-trap is closed, and the weight of the roll gradually and slowly brought to bear on the material. In about an hour and a half to two hours the rag should be entirely reduced to fibre, and the water should be running quite clear from the washer. This washing process is a very important one, and needs great care and attention, for mistakes made here can afterwards only be partly rectified in the beater. A badly broken-in engine of half-stuff will never make a close, even, and firm sheet of finished paper. Before the bleaching-liquor is run in, all signs of the textile nature of the material should have been destroyed, so as to enable the chlorine to get at the fibre at once. The roll should now be raised so as just to scrape the plate, in order to teaze out all lumps and threads, and to render the whole a homogeneous mass. The washer being raised and the water-pipe shut, the requisite amount of bleach liquor is run in and allowed to travel round with the stuff until it has brought it to as white a colour as the material will admit of. This occupies from one-quarter of an hour to an hour, depending on the quantities of the rag. Some of the coarser grades require the use of a little alum (about 2 lbs. to the engine) to strengthen the action of the chlorine; and those strongly coloured or very dirty need the application of heat to disengage the bleaching agent more thoroughly, by admitting steam into the engine. Care must be taken not to overheat the stuff, a temperature about lukewarm being sufficient in most cases; overheating tends to weaken the fibre. The heat should not be turned on until the bleach is well mixed with the stuff, as heat liberates chlorine rapidly, and, were the liquor run into an engine already heated, part of the chlorine would be wasted.

Before running the half-stuff into the beater, as much of the chlorine as possible should be washed out from the stuff. Sufficient time should be allowed to give it at least half an hour's good washing. Traces of chlorine will always remain more or less in the stuff, which must be eliminated in the beater by the use of an antichlor. No free chlorine should be allowed to remain in the pulp, otherwise, besides killing any vegetable colouring matter in the paper, it will act on the fibre, and if present in a large quantity will eventually render the paper rotten and brittle.

As previously mentioned, very little work is required to disintegrate esparto grass in the washing-engine or breaker. The roll is therefore lowered until it just touches the plate, at which position it remains throughout the operation. The washing process, in connection with esparto grass, plays a much more important part than with rags. In the latter it amounts to a simple washing and cleansing of the fibres. As has been shown, in dealing with the former fibre microscopically, most of the siliceous particles, outer cuticle and weak cellular tissue of the grass, which is easily broken up by the action of the roll, is carried away by the wash-water. The longer the washing is continued, the better is the colour produced in bleaching, since the wash-water carries away with it that portion of the material which, being less pure than the true woody fibre, opposes greater resistance to the action of the bleaching agent.

In a mill with which the Author is well acquainted, before the direct system was introduced, the grass was washed and bleached in large engines, each operation lasting three hours. The quantity of liquor necessary to bleach it to a good white colour was 11¼ gallons per cwt. On the introduction of the direct system, however, the grass could only remain in the breaker as long as the beater, on an average three hours, thus allowing only half the time for each operation. The amount of bleaching liquor then required to produce the same degree of whiteness was 16½ gallons per cwt.

As regards the bleaching and subsequent washing, the grass is treated much in the same way as rag, except that it requires to be heated to a much greater extent to complete the action of the chlorine. A heat of 120° to 130° is sufficient; anything above that is injurious, not only weakening the material but affecting the colour. Before the discovery of the bleaching properties of chlorides and chlorine gas, only the purest and whitest rags could be employed for the manufacture of fine papers. But now the coarsest and most highly coloured materials can by judicious treatment in boiling and bleaching be made to produce paper of a certain degree of whiteness.

The chlorine can be brought to act on the material either directly as gas or through the medium of a solution of bleaching powder. Bleaching by gas has almost entirely given way to bleaching with a solution in the engine, except perhaps as a preliminary operation in mills using the lowest and coarsest materials. This is due principally to the violent action of the gas, which tends to attack the fibres as well as the colouring matters. It is also very offensive and poisonous in the workroom, and as a bleaching solution is as effective in its results, it has been naturally preferred.

The commercial bleaching powder consists of an intimate mixture of hypochlorite of lime and chloride of calcium in the form of a white powder. It is only the hypochlorite, however, which is available for bleaching. Chlorine has a strong affinity for hydrogen, and when it comes into contact with water, the presence of which is always necessary in bleaching, combines with the hydrogen to form hydrochloric acid, liberating the oxygen which, in its nascent state as ozone, oxidises all vegetable substances, and which is therefore the real bleaching element. The solution is easily made in circular vats furnished with revolving agitators, by which the powder is thoroughly stirred up with the water, and all the soluble portion dissolved. The mixture is then allowed to settle, and the clear liquid is run off. The solution as used in the engine will be of a specific gravity of about 1·025, or 5° of Twaddell's hydrometer. The best Spanish esparto requires from 12 to 16 gallons of this solution per cwt. to produce a good white paper; cotton rags take from 3 to 10 gallons per cwt. according to quality; and linen from 10 to 19 gallons. Or with respect to the quantity per cwt. of paper made, which is the best criterion, the amount for grass is 22 to 30 gallons per cwt.; for cotton rags 3 to 11 gallons; and for linen rags from 11 to 24 gallons per cwt.

Sulphuric acid or vitriol, and alum, are used as agents for intensifying the action of the chlorine when dealing with the coarser and more refractory materials. Vitriol should be avoided if possible, unless it can be eliminated afterwards by thorough washing, as it is most detrimental in corroding the machine-wire. Alum or sulphate of alumina is, however, much used, and to advantage. Its liberation of the chlorine being slow and gradual allows the bleaching agent to take full effect on the material.

The process of bleaching occasions a certain amount of waste of the material. Prouteaux estimates it at from 1·5 to 3·5 per cent. for the finer rags, and from 2·8 to 7·5 per cent. for the coarser grades.

The wash-water, or water used in the preparation of the pulp should be as pure, clean, and free from mechanical and chemical impurities as possible. The presence of iron salts is especially detrimental, as the iron is precipitated by the action of the different chemicals in the form of rust, and shows as red spots in the paper. Although the proportion of these salts be insignificant, still the quantity of water that comes in contact with the material is so enormous that the total quantity of iron may be considerable.

Chemical impurities, however, cannot easily be eliminated, the only remedy being the choice of the purest water obtainable for washing. But most of the mechanically suspended matter can and must be separated by filtration. A Table is given in the Appendix comparing the losses on the various grades and classes of rags and esparto, during the several processes through which they have passed.

The further and final reduction of the fibre to pulp, technically known as "beating," together with the addition of size, starch, colour, and other necessary ingredients, is all that now remains to be done before the stuff is ready to pass on to the machine. This last operation is the most important of all, requiring skilful and delicate manipulation, and the greatest care and attention.

Since the best and closest papers are made by a judicious mixture of the different fibres, rather than by the use of one fibre alone, the quantities and quality of each varying according to the character required in the finished paper, it is in this mixture—in blending the different qualities in proportions that shall ensure the paper answering in every respect the purpose for which it is intended—that the paper-maker displays his knowledge and judgment.

As each kind of material, whether linen, cotton, or esparto, whether worn or unused, requires a different manipulation in the engines, the different stuffs are best kept separate throughout the manufacture until they are run into the stuff-chests. Here they are thoroughly incorporated with one another by a slight agitation before passing on to the machine. No rule can be given for the proper admixture of qualities to produce a given paper, nor for the manner of manipulating the fibre in the beater; the only guide is continued and lengthy experience.

In the majority of instances the best classes of rags are used for the finest grades of paper, and the coarser kinds for the lower qualities. By energetic treatment and judicious colouring, it is possible to produce fine-looking paper from the coarser materials; but the excessive waste that occurs, considerably increasing the cost of the material, has to be taken into account. This appearance, besides, is only "doctored," and is never as permanent or so good as that which is inherent in the material.

Printers and typers demand a soft impressionable paper, best obtained by the use of grass and worn fibres, such as old cotton, and quicker beating in the engine. It is pleasanter, however, for writing purposes, to have a firm, stiff, crackling sheet, obtained by the use of more linen and unused rags, and longer and more gradual manipulation in the beater.

Thin papers, again, require longer and stronger fibres than thick papers, to make up by increased strength for their scarcity in the sheet. It is also necessary, in mixing and beating the stuff, to consider the work of the making-machine. Linen fibres absorb and carry water more readily than cotton; gradually and slowly beaten stuff is also much "wetter" than that quickly cut up. If, therefore, a thick paper were made of too much strong linen, and that slowly beaten, it would be impossible to get the water out of it while on the wire, and the paper would become crushed and spoilt at the press rolls, and would not make a uniform sheet.

As a general rule, in treating rags, all the work done on the fibres to reduce them to a pulp suitable for the class of paper to be made, whether in a longer or a shorter time, should be effected gradually, the roll being lowered bit by bit on the plate, so that the fibres are rather drawn out than cut up. The full weight of the roll should not be allowed to come on the fibres longer than is necessary to bring them to a sufficiently fine and even state. The time that this may take will depend upon the sharpness of the bars of the roll and plate, on the speed of the roll, on the material used, and on the time that the stuff has been in the engine. If the work has not been brought on quick enough, and the pulp has been allowed to become what is technically termed "too wet," it will not be possible to get the pulp fine enough in the time; and either it must be sent down to the stuff-chest too long in the fibre, or, if fine enough, so "wet" that the water cannot properly be removed from it while on the machine-wire. In either case the sheet of paper, although firm and strong, will look irregular, uneven, and ugly. On the other hand, if the roll is lowered too quickly on the plate, the stuff will be cut up and will not carry water to put it together on the wire, or be what is termed "fast." The resulting sheet of paper will not only have a poor-looking appearance, but be wanting in strength and firmness.

In the case of esparto, where the fibre is already fine and short, all that is required in the beater is to complete the thorough disintegration of the fibres begun in the breaker, and, by causing the pulp to absorb the water, to render it sufficiently firm and stiff to make the required weight of paper on the machine. For this purpose the engine for treating grass should be furnished very thick—the thicker the better, so long as the grass travels,—and the full weight of the roll is lowered on the plate, and allowed to remain there until the pulp has reached the proper degree of consistency and "wetness."

Before running the pulp into the chest the roll should be raised so as just to brush the plate, and no more, for a few minutes. This serves to "clear the stuff"; that is, it opens up all knots, draws out any irregularly-divided portions, and renders the pulp uniform and clear. A simple expedient is adopted for examining the pulp in the beater, to determine the degree of fineness and uniformity to which it has been brought. A small quantity of the pulp is diluted with a large quantity of water, to render it transparent, in a circular vessel, or hand-bowl of copper or gutta-percha, the darker the colour the better for easier examination. On pouring the contents over the edge of the hand-bowl, the fibres, as they flow over, arrange themselves parallel to the current of water, and their length can be easily examined, and any knots or irregularly-divided portions detected.

The time for which the stuff is allowed to remain in the beater varies greatly, according to the paper to be made. For very thick papers and blottings, an hour and a half to two hours is sufficient; while for bank papers, loans, and very strong papers, four or five hours, and sometimes even twelve hours, are required.

However well the liquor has been washed out of the breaker after bleaching, there will always remain traces of chlorine in the pulp, which, if not neutralized, will act on the fibres and attack the iron of the drying cylinders, forming iron salts, which appear in the paper as rust. It also damages the sizing properties of the engine-size, and is very injurious to animal size, decomposing the glutinous matter and rendering it of no avail.

These traces must be entirely neutralized as soon as the half-stuff is let into the beater, and this is effected by an antichlor such as sulphite or hyposulphite of soda, which takes up the free chlorine in the pulp, forming sulphate of soda and chloride of sodium, or common salt, both of which are soluble. A simple and delicate test, for determining when the chlorine is entirely neutralized, is based upon the peculiar blue colour produced by the contact of free iodine with starch. A mixture of one part of iodide of potassium, two parts of starch, and three of water is used. The chlorine forms, with the potassium, chloride of potassium, liberating the iodine, which, combining with the starch, produces the characteristic blue colour. The object of the starch is to bind together and unite the fibres of the paper, and to render them denser, stiffer, and less spongy; in fact it is used much in the same way and with the same object as for laundry purposes. The usual proportion in the paper is from 2 to 4 per cent., or even more, for the higher classes of writings, where a stiff crackling sheet is desired. The starch is either reduced to a liquid paste with water, and introduced into the engine direct, or mixed with the engine-size; either way it seems to have the same effect. Some paper-makers say that when mixed with the size it improves it, by retarding the precipitation of the resin by the alum, thereby rendering the sizing more uniform.

Falling prices and increased competition have, in the paper-trade, as in most other trades, given rise to adulteration. In paper-making this consists in adding to the pulp kaolin, or China clay, Terra Alba, or precipitated sulphate of lime, or pearl-hardening; all except the last are more or less pure alumina, which increases the weight of the paper at a much less cost than that of raw material. In some cases the addition of a small portion of clay may be an advantage, giving a greater smoothness, softness, and opacity to the paper; but at best it is only a form of adulteration, and if introduced in large quantities renders the paper brittle and weak. Such papers as are used for writing and printing purposes can be made to carry with ease from 10 to 15 per cent. of their weight of clay, and in very thick papers 18 to 20 per cent. In the lower classes, such as wrappings, the loading enters into their composition to the extent of more than 25 per cent. A simple test of the proportion of loading in any given paper is by burning it, and weighing the sheet before, and its ashes after. The weight of the ashes indicates the percentage of this fire-resisting material. In order that the addition of the clay shall deteriorate the quality of the paper as little as possible, the stuff should be drawn carefully in the beater, and sent down to the machine longer and wetter in the fibre than if the paper were to be made with no loading. The want of strength in the clay must be remedied, as far as possible, by the increased strength and length of the fibres. The more finely divided the clay can be introduced into the pulp, the better will it mix and adhere to the fibres, and less of it will be carried away by the waste-water from the machine-wire. A good method of preparing the clay for the engine is as follows. The loading is first mixed with powdered starch, in the proportion of 1 cwt. of starch per ton of clay, in circular mixers fitted with revolving agitators. When thoroughly incorporated, the mixture is strained through a "search" into another series of mixers furnished with steam-pipes. The mixture is here boiled, which not only assists in thoroughly disintegrating the clay, but also keeps it in a better state of suspension in the water. The loading should be mixed with the pulp before the addition of the engine-size, which then appears to envelop the fibre and loading together, and enables the paper to hold it better.

Whatever quality of material is used in the manufacture, and however well it has been bleached, the finished paper will always have a more or less yellowish tinge. In some of the higher classes this pure natural colour is preferred, and the paper is allowed to retain it; but as a rule, all papers are toned to produce as pure a white as the quality of the material will admit. The colour recognized as white is made up of the combination, in their proper proportions, of the rays of the three primary colours, yellow, red, and blue. The pulp has naturally a yellowish tinge; if, therefore, the necessary quantities of red and blue, in the form of pigments, are added, the desired white shade will be produced. In the higher class papers the colours used for this purpose are, ultramarine blue and carmine, the former a dry, deep blue powder, and the latter a liquid produced by the mixture of carnation paste, ammonia, cream of tartar, and water, in the following proportions:—Carnation paste, 54 lbs.; liquid ammonia, 7 lbs.; cream of tartar, 9 ozs.; water, 36 gallons. In addition to these two colours, a great variety of others is required in the manufacture of papers of different tints, all of which, with one or two exceptions, must be mixed with the pulp in the engine. It is not the object of this Paper to deal with the colouring of the pulp, which embraces a considerable knowledge of the different pigments and their proper admixture, and which comes more under the province of the colour-man than the paper-maker.

Besides these materials, more or less "engine-size" has to be added to the pulp to render the paper non-absorbent of ink. It consists of a resinous alumina, which adheres to and envelops the fibres, and is precipitated by the addition of alum or sulphate of alumina to a soap of resin. But this will be dealt with more fully when comparing the respective merits of animal-sized and engine-sized papers.

From the beaters the pulp flows down leaden pipes into the large circular vats or closets, known as "stuff-chests." They hold from 1,000 to 2,000 lbs. of pulp, which is pumped from them up to the machine. Each machine should be provided with at least two of these chests, so that, when one is in use, the other is empty and ready for a fresh supply of pulp from the beaters. They can be constructed of stone, or concrete rendered with cement; and are furnished with a very slowly-revolving agitator, just sufficient to keep the pulp in motion, and prevent settlement of the heavier portions.

The main object of the paper-making machine is to produce from the prepared pulp a close, even and firm felted and continuous web of paper of any desired width and weight. The various operations performed on the pulp by this machine may be classed as follows:—Settling, or extracting from it, as far as possible by settlement, all dust, sand, and foreign substances that are still contained in the pulp. Straining, to keep back all knots, threads, and light impurities from passing on to the wire, and thus to render the pulp more uniform. Interlacing the fibres of the pulp together on the machine-wire, by means of water and lateral shake. Giving the character to the paper by the impression of the "dandy-roll." Extracting the water from the web by a strong natural suction. "Couching" the web, to press out most of the remaining water, and to squeeze the pulp into a felted web, between heavy felt-covered rolls. Pressing the web between brass and felt-covered rollers. Drying the web over revolving cylinders filled with steam. The actual operation of forming the paper begins as soon as the pulp reaches the wire, and is completed after the web has left the couch-roll. All the other steps are subsidiary operations; and it is here where the greatest care and attention have to be paid, and where experience is demanded.

As previously mentioned, there are two distinct processes of producing the finished paper from the prepared pulp, known respectively as hand-made and machine-made. Hand-made paper, except for certain of the best classes, has been almost superseded by machine-made, the expense of manufacture, and consequent high price, rendering it too costly for ordinary use. In making paper by hand the pulp, diluted with a sufficient quantity of water, which is used throughout the manufacture as a means of carrying the material through the different processes to which it is submitted, is emptied into a vat. The paper-maker or vat-man, standing alongside this vat, dips a mould into the pulp and takes out a sufficient quantity to form a sheet of paper. The mould consists of a wooden frame, covered over the bottom with a fine wire-cloth, and surrounded by an elevated border on the top, called the "deckel," which determines the size of the sheet. The texture of the wire-cloth gives to the paper its character, whether laid or ribbed, or wove, or watermarked. While the water is straining through the wire, the man shakes the frame to and fro in every direction to interlace the fibres thoroughly together, and distribute the pulp as uniformly as possible over the surface of the mould. When the sheet is formed, the deckel is removed, and the "coucher" takes the mould and applies a felt to the sheet, and by a dexterous turn lays the whole sheet upon it and gives back the mould to the vat-man. This is called "couching the sheet." On this is placed another felt, and then a fresh sheet from the mould, and so on, until a pile is accumulated, called a "post" or "bale," consisting of about eight quires or one hundred and ninety-two sheets. The post completed, it is placed under a hydraulic press, and subjected to a considerable pressure to force the water out. When sufficiently pressed, the work of a third hand, called the "layman," begins, who takes the sheets carefully from the felts and lays them into a post of themselves. In some mills the sheets are now taken to the drying loft, but if a superior quality of paper is desired, it is necessary to lift and exchange the leaves. In the exchange, the leaves of two posts are lifted one by one and formed into a fresh post, in such a manner that their position in the pile is changed. After four or five operations of this nature, alternately with a gradually increasing pressure, the leaves are hung up in a loft to dry. This repeated exchange and pressure is said to give the characteristic mellowness and velvety feel to hand-made paper.[1] When dry the sheets are sized, being passed by hand between felts through a solution of animal glue well heated, which thoroughly penetrates the paper. The sheets are then hung up again to dry, and then flattened out and glazed between rollers.

This process is a slow and laborious one. In the year 1798 at the French mill at Essonne, a man named Louis Robert, conceived the idea of a machine for producing a continuous sheet of paper. A patent was granted to him, and a reward of 8,000 francs by the French Government. Owing, however, to the disordered state of the country at that time, Robert was unable to bring his ideas to perfection, and Mr. Leger-Didot, proprietor of the mill, bought the patent from Robert, and went over to England in search of some one to work out the idea with him. Mr. Fourdrinier, proprietor of the Dartford mill, got hold of it, and, aided by the mechanical knowledge of Mr. Donkin, after patient toil and perseverance, attended with great expense, for which he received no recompense, succeeded in 1803 in building a machine, which worked tolerably well.

This machine, by the subsequent improvements of Dickinson, Causon, Crompton, and others, has been brought to the state in which it now is, and may truly be said to be one of the most beautiful combinations of mechanism yet invented (Plate 7). It embraces a multitude of the most ingenious and delicate operations, and produces in a few minutes, and in one process, from the prepared pulp, sheets of paper ready to be baled up for the market. As before stated, it has almost driven hand-made paper from the market. Still, as is almost invariably the case where a hand-made and a machine process are compared, there are points in the former which it is impossible to imitate in the latter; and probably hand-made paper will always find a market.

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[1] "Guide Pratique de la Fabrication du Papier et du Carton." Par A. Prouteaux. Paris, 1864.

There is a strength and smoothness, a pleasant glossiness of surface in hand-made paper, which has not yet been imitated by the machine. This is probably due, in part, to the more complete interlacing of the fibres by the hand-shake than by the machine-shake; in part, also, to more time being allowed for the water to drain off the wire, thus enabling the pulp to be beaten longer and wetter in the fibre. Nor is it possible on the machine to imitate the heavy and continuous pressure to which the sheets in hand-made paper are subjected—a pressure which is said to impart the characteristic firmness and smoothness to hand-made paper, and which is not equalled by the corresponding process on the machine of passing the web between felt-covered rolls. Lastly, the continual state of tension of the web on the machine between the various press-rolls and drying cylinders—a tension that is increased by the contraction of the paper in drying—must draw the fibres apart from one another, and weaken the strength and firmness of the sheet. Certain special papers, such as bank-notes, stamp-papers, deeds, in one word, all papers in which durability is the chief requirement, are better adapted to the vat than to the machine. On the other hand, the machine is peculiarly suited for making thin papers, which are not easily made by hand without risk of great damage in the couching department from the difficulty in transferring the sheet whole to the felt. The entire process on the machine occupies at most only a few minutes, which, in the ordinary state of the weather, could not be done in less than a week by hand.

On Plate 7 are given the plan and elevation of a 96-inch machine, made by Messrs. James Bertram and Son, Edinburgh. The stuff-chests are usually sunk into the ground to allow the pulp to flow from the beaters. It is then pumped up on to the screen or sand-table. For this purpose an ordinary plunger-pump, fitted with ball or Perraux valves, is most suitable, all the metal coming in contact with the stuff being of brass or brass-lined.

The following diagrams and description of the Perraux valve and pump are taken from a paper entitled "L'industrie du papier à l'exposition de Vienne." The valve, Fig. 3 (p. 284), is of gutta-percha; the piston, Fig. 4, is of cylindrical form in its lower part, and divided into two lips terminating in a point. This conical part is flattened and split at the top in such a manner that, under a pressure from above, the two lips are closely shut one against the other, and permit the pulp to be forced up. A valve of the same nature at the lower part of the pumps, or at the end of the pipe from the stuff-chest, acts in the same way as an ordinary force-pump. This arrangement answers admirably for pumping semi-fluid substances like paper-pulp.

Fig. 3.

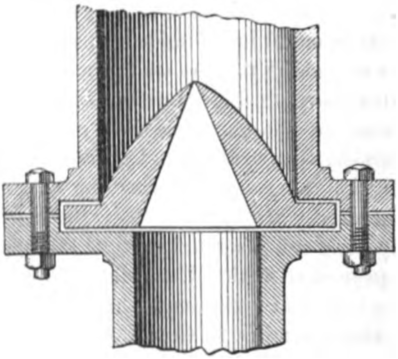
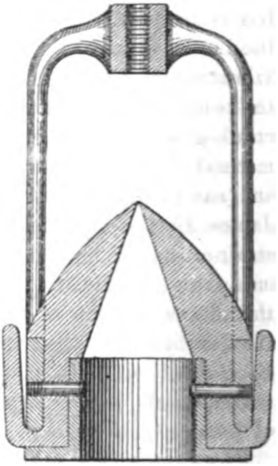


Fig. 4.



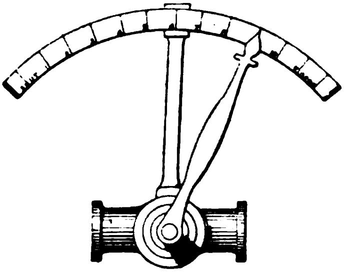
The stuff-pump discharges into a long upright box. At the bottom of the box a small sluice, worked by a screw, regulates the supply of pulp to the machine. There is also an overflow-pipe in the box taking back into the chest all the surplus. Since the pulp, as let down from the beaters, is never sufficiently diluted for working, there is also another box or tank supplied with water by a separate pump, with sluice and discharge-pipe for regulating the supply to the pulp. The water and pulp mix together, and flow on to the screen or sand-table. This consists of an elevated table, in which is sunk a shallow serpentine channel lined on the bottom with rough felt, and divided throughout its length by a number of small weirs, behind which the impurities settle and collect as the pulp flows over them on its way to the strainer. These sand-tables should be frequently cleaned and washed out, especially when working on low-classed papers.

The strainers or knotters consist of plates of brass or some hard and durable composition, about ¼-inch to ⅜-inch thick, with fine parallel slits cut in them through which the stuff passes, all knots and improperly divided portions remaining behind. They can be made to act in two ways, by vibration or by suction, or sometimes a combination of the two. For fine writings, where the stuff is carefully watched and prepared in the beating-engine, one straining through a finely cut suction-strainer is sufficient. The suction-strainer consists usually of a box covered with square or circular plates. This revolves in a square vat containing the pulp made to pass through the plates by strong suction. The interior of the box is connected through a stuffing-gland with a pipe leading to the breast of the machine. The suction is obtained by the rapid vibration of a series of leather or india-rubber bellows fitted in the centre of the strainer, and driven, at a high speed, by suitable crank-gearing from the outside. A great improvement on this method of obtaining suction, both as regards quietness in working and saving of wear and tear, has been brought out by Messrs. James Bertram and Sons, of Edinburgh. It is produced in each strainer by an air-pump operating upon a flexible sheet, carried on a frame inside the strainer, and lying parallel with each side of the plates. The pulp never enters the pump, and only touches the flexible sheet before passing out at the delivery-box. (Plate 7.) Each machine should be provided with at least two strainers, and, perhaps, one of a larger cut suitable for working a different class of pulp.

From the strainers the pulp passes on to the wire of the machine. One of the first duties of the man on starting the machine is to adjust the amount of pulp flowing on to the wire, to produce the required weight of paper at the end of the machine. To accomplish this the foreman takes a piece of the paper as it leaves the last drying cylinder, and, cutting it to the required size, weighs it. If it is too heavy, the sluice at the bottom of the pulp-box must be closed a little, or the speed of the machine quickened, or *vice versâ*. He does one or other according to the character of the pulp, driving the machine as quickly as is consistent with producing good paper. Since it is impossible for the machine-man to be sure of the weight until a considerable amount of paper has passed over the machine, it is obvious that the means for raising and lowering the sluice of the pulp-box should be as delicate as possible, so that the man may be able to adjust the weight at once to a nicety. The sluice is generally worked by a fine screw; but the Author has seen a neat contrivance for effecting greater accuracy in its adjustment. It consists of an ordinary horizontal plug-cock (Fig. 5) in the bottom of the pulp-box, to the plug of which is fastened a long arm or pointer, marking on a graduated arc the amount of opening of the sluice.

The wire consists of a continuous woven brass cloth, supported horizontally by a series of small "tube-rolls" in a frame. It is stretched tight over two rolls, one at each end of the frame, called the "breast-roll" and the "lower couch-roll," which should be made rigid enough not to yield at all under the excessive tension. The ordinary gauge for the wire is 66 meshes to the inch for writings and printings. Finer wires are used, however, up to 80 to the inch. For lower grades the mesh is coarser.

FIG. 5.



As much water should be abstracted from the web as possible while on the wire. It passes through the meshes of the wire at the lines of contact between it and the tube-rolls. These latter should therefore be numerous. The water flowing from the wire, which contains a considerable percentage of fibre, especially from finely beaten pulps, drops into a flat copper-vat, from which it flows into a tank, and is pumped up with the water for diluting the pulp, so that none of it shall be wasted.

From the tube-rolls the wire conveys the pulp over a pair of suction-boxes for extracting the remaining water from the web, and then between a pair of heavy felt-covered couch-rolls, after which the web leaves it. The wire, passing round the lower couch-roll, is carried back to the breast-roll over a number of small wooden-rollers.

The width of the web of paper is determined by two continuous straps of vulcanized rubber about 1½ inch square, one on each side of the wire, called the "deckel-straps." The distance between these straps, which travel along the wire and at the same speed, can be increased or diminished. They run over flanged brass pulleys, and guide the pulp from the moment it spreads on the wire until it arrives at the first suction-box, where the web is sufficiently dry to retain its edges.

The frame of the machine, from the breast-roll to the first suction-box, is hung on a pair of strong hinges, and is capable of a slight horizontal motion, imparted by a horizontal connecting-rod, one end of which is eccentrically keyed on to the face of a rapidly revolving disk driven by a pair of speed-cones, so that the speed of the shake can be altered. This motion, therefore, known as the "shake," is greatest at the breast-roll and decreases as the pulp travels along the wire. It is at most very slight, about ⅛ inch more or less.

The principle object of this shake is to interlace the fibres together; but it also assists in keeping the water from passing through the wire too rapidly before the paper has been properly formed. This shake and water are the two great factors by means of which the machine-man forms the paper; and he must so regulate the two as to make the closest and best looking sheet of paper possible from the pulp. It is evident that the shake will have little or no effect on the fibres unless they are floating in water, and therefore the water must be prevented leaving the pulp before the shake has done its work. The more rapid the shake, the less quickly will the water leave the wire; and the slower the shake, the easier will the water pass through it. If there is sufficient shake to interlace the fibres together, and the pulp still looks dry on the wire, more water must be added by opening the sluice at the bottom of the water-box. This is characteristic of quickly beaten, or "fast" stuff. Again, there may be as much water in the pulp itself as can be taken from it by the drainage from the wire and the suction-boxes, and if the sheet of paper looks wild and open, a little more shake may be necessary to close it better; this is generally the character of long and wet stuff. Much discretion must therefore be exercised, in regulating the amount of shake and the quantity of water, to suit the character of the pulp. The speed at which the machine is driven must be also taken into consideration. The quicker the speed, the less time will there be for the shake to form the paper and for the water to leave the pulp; and in some cases, in dealing with "wet" pulps or the thicker weights of paper, the speed of the machine must be diminished. No rule can be given for this, as the character of different pulps, depending partly on the admixture of material, and partly on the mode of manipulation in the beating-engine, varies so greatly, and sometimes in so unaccountable a manner, that experience can be the only guide.

As regards the length of the wire-cloth, it is evident that the greater the distance between the breast and the suction-box, the longer time will there be to shake the pulp together, or in other words the quicker can the machine be driven. Since it has become possible to weave wires 50 feet long, this distance has been much increased on machines, and is now generally not less than 11 or 12 feet.

The water that will not leave the pulp on the wire must be taken from it by suction. Most machines have two suction-boxes with the " dandy-roll " revolving between them; so-called because it can be made to give to the paper any desired appearance. The web, to receive and retain any mark or character, must neither be in too dry nor in too wet a state, but just moist enough to be capable of receiving a clear impression, and just sufficiently dry to retain that impression permanently. The first suction-box regulates the amount of moisture in the web necessary to give a clear impression, the remaining moisture being extracted by the second. The suction-boxes are of wood or metal, and air-tight, having no communication with the air except through the wire. The water is drawn into them by suction-pumps as the web passes over. The boxes are fitted at each end with movable air-tight heads, adjustable with the deckel-straps, so that the space between them and the width of the web is the same.

The process of water-marking machine-made paper was for some time considered an impossibility; but it is now effectually and ingeniously accomplished. The dandy-roll, a light cylinder consisting of a narrow brass-tube, on which are soldered a number of brass rings or spiders of about 4 to 6 inches in diameter, is placed in framings so as to rest across and upon the wire-cloth, and to be moved by it. The cylinder is covered with wire-cloth, wove or laid or linear, on which small pieces of wire are soldered representing the letters or devices to be reproduced in the web. From the second vacuum-box the web passes between the couch-rolls, so called from the corresponding operation of couching in handmade paper, which, by pressing out most of the remaining moisture, impart sufficient consistency to the paper to enable it to leave the wire. Both rolls are covered with a felt-jacket, and the top one is provided with levers and weights to increase or diminish the pressure on the web.

The paper is now fully formed, and passes between one pair or preferably two pairs of press-rolls to extract the remaining moisture, and to obliterate as much as possible the impression of the wire-cloth from the under side of the web. It is carried from the couch-roll by a travelling felt through the rolls of the first or "wet-press." The rolls are of cast-iron cased with a brass-shell shrunk on; the pressure between them on the web can be increased by a screw-press acting on the journals at each end of the top roll. In the first press the upper surface of the web is in contact with the brass, and is therefore rendered smoother than the lower surface which rests on the felt. As it is important that both surfaces of the paper shall be nearly alike, the action of the first press must be reversed in the second, the felt being in contact with the upper and the brass with the under surface.

The paper is finally dried by passing it over a series of hollow cast-iron cylinders heated with steam, and driven one from the other by gearing. The slower and more gradual the drying process, the better, as the change on the fibres of the web due to the rapid contraction is thereby not so excessive, and the heat required at one time is not so great nor so likely to damage the quality of the paper. The heating-surface should therefore be as large as possible. A great number of cylinders is required now that machines are driven at such high speeds. The usual number is from ten to twelve, of from 3 to 4 feet in diameter, giving a heating-surface of from 120 to 140 square feet per foot width of web. If much larger in diameter, too great a proportion of heat would be lost by radiation from the ends. The cylinders are so placed that both surfaces of the web are alternately in contact with the heating-surface.

All the cylinders, except the first two or three with which the moist paper comes in contact, and where the greatest evaporation occurs, are encased with felts. The object of these felts is principally to keep the web of paper flat against the drying-surface and to prevent wrinkling; provided the paper is not too moist, nor too rapidly passed over the cylinders, these felts also assist in the drying if they have time to become dry while passing back again to the first cylinder. To assist the drying of the felts in machines made to travel at high speeds, they pass over, in their return journey, small cylinders filled with steam.

The usual mode of heating the cylinders is by a branch pipe to each from a main steam-pipe extending alongside the machine. By this method the amount of heat apportioned to each is regulated by a cock. The best method of drying the paper would seem to be to extract an equal amount of moisture at each cylinder as the paper is moved along, so that the first cylinder reached by the paper should be the coolest and the last the hottest. It needs only a slight heat to dry a damp sheet, but, as the paper dries, it would take a greater degree of heat to evaporate the remaining moisture in the same time. With a separate steam-pipe to each cylinder it would be difficult for the machine-man to keep them at a gradually increasing temperature; and it would seem a better plan to lead the steam directly only into the last one, and to allow it to exhaust from one to the other. This would ensure the temperature decreasing gradually to the first drying cylinder. The drying of the paper is costly, necessitating a considerable expenditure on fuel. Hoffmann, in his treatise on paper-making, asserts that it has been found by theoretic calculation, as well as from experience, that about ½ lb. of coal is required to produce steam enough to dry 1 lb. of paper.[1]

The web of paper, in passing from the couch-roll through the press-rolls and over the drying-cylinders, is in a state of continuous tension; this is increased considerably by its tendency to contract in drying which is forcibly prevented. The paper is, however, free to contract across the web, and the web measures from 1½ inch to 3 inches wider on the wire than it does at the end of the machine. Papers of different materials, and more particularly of different weights, stretch more or less between the different presses. For thin papers the presses require to be driven a little faster to prevent the web creasing under the roll; but a similar degree of tension would break the web if applied to thick papers. In working different weights and classes of paper, therefore, the relative speed of the different parts may have to vary slightly. This is especially the case with water-marked papers, where the distance between each impression must be of a given length and remain constant. The variation of speed is usually effected by laying strips of felt or canvas, smeared with resin, on the driving-pulley of the part to be accelerated. This is a rough expedient and, if expansion-pulleys could be designed of simple construction and easily worked while the machine is in motion, they would be a great addition to it.

The web of paper when dried is wound up in long reels over wooden cores, impelled by gearing through the medium of a friction-pulley, so that the reel, driven by friction only, decreases in its number of revolutions as the diameter of the roll of paper increases.

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[1] "A Practical Treatise on the Manufacture of Paper in all its branches," by Carl Hoffmann, 1873.

The average speed of a paper-machine on fine writings of medium weight is from 60 to 70 feet per minute, but on thinner weights, the machine can be driven up to 120 feet per minute. It is, of course, the object of the paper-makers to obtain as high a speed as possible, consistent with making a good sheet of paper, as it costs little more to drive it at 80 feet a minute than at 40 feet; whereas twice the amount of paper is made at the higher speed. The speed of the machine has frequently to be altered while in motion. An alteration of a few feet a minute can be effected by changing the driving-speed of the steam-engine governor; for a greater change, the machine must be stopped, and other driving-wheels substituted, unless it is provided with a pair of high-speed cones, giving with any one set of driving-wheels speeds varying 40 to 50 feet a minute. All the different parts of the machine proper should change in speed together, so that they shall always preserve the same ratio of motion one to the other. The stuff-chests and pumps, strainers and suction-pumps are driven direct at a constant speed from the steam-engine.

Paper for writing and printing must be non-absorbent of ink, or it would partake of the nature of blotting-paper. To render the fibres non-absorbent, some form of animal or vegetable size or glue must be applied to the paper, either as a coating on the finished web or mixed with the pulp in the beating-engine. The former process is known as "animal or tub-sizing," and the latter as "engine-sizing."

Animal-size is prepared principally from the waste cuttings and clippings of hides of oxen and bullocks of no use to the leather-merchants, and consisting of horn-piths, heads, tails, legs and belly-pieces. The methods of extraction of the size are, with various improvements, much the same now as those employed years ago; namely, soaking in boiling or almost boiling water until all the gelatine has been extracted. The hide-pieces, "scrolls" or "scrows," are first soaked in cold water to soften them, and are then cut into shavings in a machine similar to an ordinary revolving chaff-cutter. The size is obtained much quicker and better when the scrows are cut into shavings than when boiled in the piece, since they present, as shavings, a greater extent of surface to the action of the heat. It requires a higher temperature and a much longer boiling to produce size from the piece, and this tends to deteriorate its quality. Formerly, in order to facilitate the extraction of the size, the scrows were soaked in water until incipient putrefaction set in, when they were put into the boiler. In order to keep this rotten size from further putrefaction, sulphurous acid was mixed with the scrows, but this is very liable to injure its sizing properties. All these drawbacks have been overcome by cutting the hide-pieces into shavings before boiling.

After cutting, the shavings should be steeped again for some hours in cold water to swell them out and to render them thoroughly soft, so that the size may be extracted as soon as heat is applied. The object is so to prepare the scrows as to produce the size in as short a time and at as low a temperature as possible. The shavings are next put into a wooden tub fitted with a false perforated wooden bottom on which the scrows rest. Underneath the false bottom is a closed steam-coil to supply the heat. The scrows are covered with hot water, which is kept at a temperature of from 175° to 190°, depending on the kind of scrow. In about from four to six hours sufficient gelatine should have been extracted to take off a draught; and the decoction is strained off and fresh water added to the scrows. In this manner four or five draughts can be taken from one lot of clippings which are all mixed together in cisterns and allowed to cool into a jelly ready for use.

A ton of good hide-clippings will produce from 2,100 to 2,600 gallons of size, which, when diluted to a working consistency, is increased to from 2,500 to 3,100 gallons; this quantity will size from 24,000 to 48,000 lbs. of paper already about one-third sized in the engine, depending upon the thickness of paper. About 10 lbs. of alum should be added to every 100 gallons of size to preserve it from decomposing; it also diminishes the solubility of the gelatine and renders the paper sized more impermeable. To prepare the size for use it is remelted at a temperature of 115° to 120°, and diluted with water, if necessary, to such a consistency as suits the paper best for which it is to be used. Thin or open porous papers need a stronger size than thick and firm papers.

The old plan of sizing, employed still for hand-made paper, of dipping the sheets of paper into a vat filled with hot size, and then slowly drying by hanging them on rope lines or "tribbles" in a loft, is adopted in machine-mills for the better kinds of paper used for office-books, ledgers, &c., where the size has to withstand the action of strong chemicals such as red ink, and also to allow of easy erasure. The sheets remain a longer time in the size which penetrates more into the body of the paper, and they are also able to expand and contract freely in drying, which produces a stronger and firmer-sized sheet. In this method the sheets, cut straight from the machine or "waterleaf," are placed by hand between two travelling continuous felts, which carry them slowly through a long vat filled with size heated by a steam-coil to a temperature of about 115°. On delivery at the other end the paper is laid for about twelve hours in piles, to allow the size thoroughly to saturate the paper. The sheets are next hung up on the tribbles in slips of three or four sheets in steam-heated lofts to dry, at a temperature of from 80° to 120°. After about ten hours the lofts are opened to a free current of cold air; the paper is allowed thus to "weather" for two or three hours, which gives toughness to the sheet and prevents brittleness. This is, however, a lengthy and expensive process, and only available for special classes. For the generality of tub-sized papers the paper is passed through the size in the reel. An ordinary tub-sizing vat (Plate 6) consists of a shallow rectangular box or trough heated underneath by steam. This is filled with size, in which revolve four or five wooden rollers. The web of paper passes under and over these rollers and then between a pair of brass squeezing-rolls which remove the superfluous size. It has been found by direct experiment that 100 lbs. of unsized paper will absorb from 6 to 11 lbs. of gelatine, depending on the thinness of the paper. There cannot be a stronger evidence of the necessity for the stuff being well prepared, in order to obtain a sound paper, than the process of sizing. If the pulp has been slowly prepared, so as to hold a good deal of water, it will also hold and retain the size in a manner corresponding thereto; whereas quickly-prepared stuff, which has been cut rather than drawn out in the engines, not only requires a much stronger size but is sized with much greater difficulty.

The web is now dried over a long series of open skeleton drums about 4 feet in diameter, inside which revolve fans for creating a circulation of hot air. Rows of steam-pipes underneath the line of drums furnish the heat for drying. Quick and rapid drying is not only injurious to the quality of the paper, but also renders the sizing properties of the gelatine less effectual; the number of these drums is therefore very great, as many as sixty to ninety, to ensure the process being slow and gradual. The chief drawback to this form of drying is the tension again produced on the web of paper, thus prevented from contracting lengthways, after the expansion due to immersion in the size, and which tends to impair the strength and elasticity of the fibres. An ingenious process has been invented to obviate this difficulty, but it has not yet been brought into general practice. The paper, after passing through the ordinary sizing-trough and squeezing-rolls, is carried upwards on to an elevated platform, consisting of two parallel beams which can be extended to any length desired. Two endless chains travel along these beams at a low speed. A wooden hopper at the receiving-end of the machine is filled with a number of wooden spars which are picked up at regular intervals by catches fixed on to an endless belt or chain. This chain carries and delivers the spars on to the two travelling chains on the platform. The web of paper is passed over a roller, after leaving the reel, and is allowed to fall down in a festoon or loop below. The upward travelling-spar catches the web and, on its arrival at the top, is deposited with it on the two continuous chains. At regular intervals the spars travelling upwards catch the web again so as to form a succession of travelling loops or festooons. At the other end the paper is wound up on an ordinary reeling machine, the spars falling down a slide into another hopper, where they are collected and taken back to the receiving-end. The heat is provided, as with the drums, by rows of steam-pipes extending the whole length of the machine on the floor underneath, the hot air rising and circulating about the paper. These two forms of drying machines are shown on Plate 7.

The process of sizing above described, although superior to any other method, entails a large addition of plant, labour and time to the general economy of the mill; and it was therefore only natural that paper-makers should endeavour to discover a process by which the paper could be produced sized off the end of the making-machine without the necessity of any additional process. The natural bent of their investigations was to find out some material, which when mixed with the pulp in the engine would so envelop the fibres as to render them thoroughly impermeable. The result has been the process known as "engine-sizing." There are many recipes for making this size; they are, however, almost all substantially the same in principle, the base of the size being resin. It is obtained by adding a solution of alum to a resinous soap dissolved in soda. The resulting compounds are sulphate of soda and a resinous alumina which is the size.

The following is a recipe for a size, which renders the paper thoroughly non-absorbent: Take 85 lbs. of refined soda ash 57 per cent., dissolve in about 60 gallons of boiling water in a tank fitted with a steam pipe; add gradually 6 cwt. of finely ground resin to the solution, and boil the whole gently for three or four hours. Strain the mixture through a search into tubs to cool. When cool the size separates into two substances; one, the soap of resin, soft and of a light yellow colour, the other, a dark brown alkaline liquid, which rises to the top and contains the surplus soda used in dissolving the resin. The latter should be taken off, if left it injures the quality of the size. To prepare this resinous soap for the engine it is diluted with water to twelve or thirteen times its volume, producing a milk-white solution. To precipitate the size from this solution it must be mixed in the engine with an equal quantity of a solution of sulphate of alumina or alum, dissolved to a specific gravity of 1·35 (7° Twaddell). The above quantities will produce sufficient to thoroughly size 20,000 lbs. of paper. Some makers prefer to mix the starch for stiffening the paper with the size before putting it into the engine, on the ground that it improves the size and renders its precipitation more uniform.

Engine-size renders the paper fully as non-absorbent as animal-size. The latter penetrates the sheet only slightly and forms a coating or skin on each surface, whereas the engine-size surrounds each fibre and impregnates the whole mass. Surface-sizing, however, produces a stronger, firmer sheet, and is smoother for the pen to travel over; the manufacturer also gets the benefit in the price of the paper of the additional weight of the size, amounting to 7 per cent. on the average. On the other hand, as the animal-size is mostly a skin on the surface, if the coating be broken anywhere, by the use of a knife in scratching out, the paper will only imperfectly resist ink in the place, a great disadvantage for account- and office-books and ledgers. Engine-sized paper is much cheaper to produce than animal-sized, and is therefore used principally for the lower qualities of writings, and for almost all kinds of printings where firmness and smoothness are not so much a desideratum. Most tub-sized papers have a certain portion of engine-size mixed with the pulp. This not only ensures the thorough sizing of the sheet, but also is a measure of economy in reducing the absorbing power of the paper for the animal size. Papers for ledgers and office-work are best given an extra proportion of engine-size to ensure their ink-resisting properties, and they are also sized by hand in animal-size and loft-dried.

The following rough estimate of the comparative cost in materials and wages of engine-sizing and animal-sizing paper, may be of interest.

Engine-sizing, per 20,000 lbs.

	£.	s.	d.	
Materials	5	2	0	
Wages	0	12	6	
Total	5	14	6	Cost per lb. = 0·068 d.

Animal-sizing, per 20,000 lbs.

	£.	s.	d.	
Materials	36	0	0	
Wages	4	10	0	
Total	40	10	0	Cost per lb. = 0·486 d.

All the better classes of papers require smoothing or flattening on coming from the drying-cylinders of the sizing or making-machines; and a good many, especially papers for writing purposes, are wanted with a more or less high glaze on their surface. This surfacing or glazing can be done in two ways; either by hand in single sheets between a pair of rolls, or in the web through a series or stack of rolls running one upon another in an upright frame.

The hand-glazing process is adopted only for the best grades of writing-papers, as it gives a smoother, higher, and more permanent gloss than has yet been imitated by the roll-calender. In this method each sheet is placed by hand between two zinc plates, until a pile of sheets and plates has been formed sufficient to make a handful for subjecting to the glazing-rolls. This handful, of about 2 quires or 48 sheets of paper, is then passed backwards and forwards between two chilled-iron rolls gearing together. A considerable pressure can be brought to bear upon the top roll by levers and weights, or by a pair of screws. The pressure on the rolls, and the number of times the handful is passed through, is varied according to the amount of gloss required on the paper. For a mere smoothing or flattening out, specially made glazed mill-boards are substituted for the zinc plates. The hand process is an expensive and laborious one, and, where adopted, necessitates a large increase of plant and wages in the mill. A paper-mill glazing 3,250,000 lbs. of paper in a year, requires seventeen hand-machines to do the work; and the cost of this in repairs and wages amounts to fully 0·32*d.* per lb. of paper turned out.

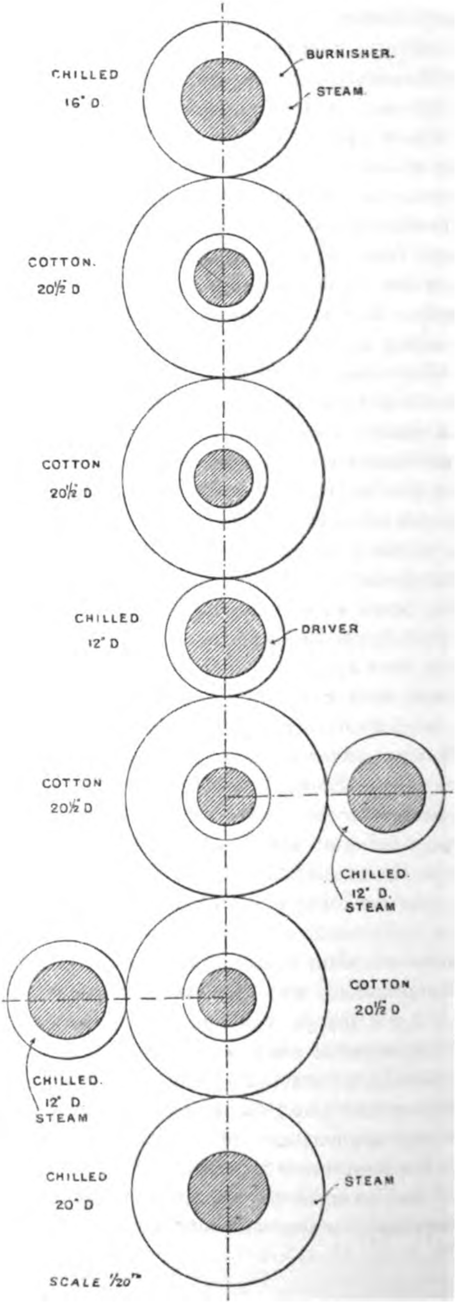
For lower surfaces and cheaper qualities the roll-calender affords a much more expeditious and inexpensive method. The paper in the web is passed in at the top of the calender and taken down through the whole stack, getting as many "nips" but one as there are rolls, and is reeled up again at the bottom. By a suitable arrangement of weights and levers a heavy pressure can be brought to bear on the rolls. As to the material of which the rolls are composed, a great deal depends upon the kind of surface, and the quality of paper to be glazed. The calender usually consists of a stack of chilled cast-iron rolls; or else, alternating rolls of chilled iron and compressed cotton or paper, so that the web at each nip is between cotton and iron. For very low surfaces a couple of nips between two cotton rolls are sufficient, producing the same style of surface as that for which the glazed mill-boards are used in the hand-glazing machines. Engine-sized papers, especially those made entirely from esparto grass, are extremely difficult to glaze, the heaviest pressure that can be applied to the rolls only producing a very indifferent gloss, besides crushing the paper and destroying its "feel" or "handle." For these papers, then, a different principle is adopted. The machines are provided with two stacks of about five or six rolls each, all of chilled iron. The web of paper is brought off the drying-cylinders slightly moist, and is passed through these calenders. To assist the surface, a pair of rolls known as "smoothing-rolls" is interposed, on machines for making engine-sized papers, halfway between the drying cylinders (Plate 7), where the paper is in a very damp state, and which imparts at once considerable smoothness to the surface. Provision is made for admitting steam to the interior of the rolls, as heat assists the glazing and helps to dry the paper at the same time. The surface produced by this method is, however, an inferior one compared to that produced by pressure. A stack of chilled rolls is not suitable for a heavy pressure; the material being unyielding, crushes the paper so entirely as to take away its character, and the web is liable to form into creases before the rolls, which not only damage the paper but tend to leave a permanent mark on the rolls themselves.

For calendered surfaces on animal-sized papers it is better to use a stack composed of cotton and chilled rolls. A heavy pressure can be applied, producing a finer and closer surface; the web is not so liable to run into creases, and if it does, causes no permanent harm to the rolls; a hard and soft surface being in contact, the hard surface seems to restore and renew the soft; and although the softer surface is easily marked by anything passing over it, the blemish is obliterated again by pressure against the harder iron surface. Fig. 6 (p. 298) is a sketch of an excellent arrangement of the rolls in such a calender, which will surface paper at the rate of 300 lineal feet of web per minute.

The glaze produced by the web-calender, is never, however, equal for gloss and smoothness to that obtained by the hand-glazing process between zinc plates, presumably due to the greater softness of the material, and closeness of the surface of zinc to that of iron. An attempt has been made to produce this in a calender by rolls covered with a zinc shell; and the Author has seen a good imitation of a hand-glazed surface by this means, but it has not yet been brought to a state of practical perfection.

A very high surface can be quickly given to paper by friction with the assistance of heat. The process is known as "burnishing," and is used mostly for envelope papers and some classes of wrappings, where one surface only of the web is re-

Fig. 6.


CHILLED
16" D.
BURNISHER.
STEAM.
COTTON.
20½" D
COTTON
20½" D
CHILLED
12" D
DRIVER
COTTON
20½" D
CHILLED.
12" D.
STEAM
COTTON
20½ D
CHILLED.
12" D
STEAM
CHILLED
20" D
STEAM
SCALE 1/20th

quired to be glazed. It is produced by a chilled-iron roll on one of cotton or paper, the ratio of the revolutions being as 4 : 5 or ⅕ friction. Steam is admitted to the burnishing-iron roll. The highest pressure exerted on the web of paper as it passes between the rolls to produce a very high gloss, both in hand- and calender-glazing, amounts to from ¾ to 1 ton per inch width of web.

The cutting of the web into sheets is effected by two kinds of machines, known as the single-sheet cutter and the revolving cutter. The latter consists of a revolving knife, capable of cutting the full length of the web at one stroke. The number of revolutions of this knife is adjustable, so as to cut the sheet to any required length. Before coming to the revolving knife, the web passes under a number of circular knives or slitters revolving on a shaft parallel to the large knife. The position of these slitters can be adjusted on the shaft, so as to cut the web crosswise into the number of sheets required, and at the same time to remove the rough edges formed by the deckels. A travelling continuous felt carries the sheets from the cutter to a table, where they are laid in piles. A number of reels are cut at one time on this machine, all passing under the knives together. For cutting papers with great accuracy, such as water-marked papers, where the impression must appear exactly in the same position in each sheet, every web must be dealt with separately sheet by sheet. The web is carried from the reel over a large oscillating drum. During the forward motion of this drum the paper, which is kept close to it by a pair of rollers, is brought up to the knife. By a suitable mechanical arrangement a bridge clamps the sheet, and the knife cuts it; while the drum travels back again for another sheet. The amount of travel of the drum is regulated to produce a sheet of the desired length, and a boy, by noticing where the water-mark appears when the sheet is being cut, can, by regulating the travel of the drum, correct any variation in its position.

All that now remains to be done before taking the paper to market, is overhauling. This consists in sorting out all speckled, spotted, or damaged sheets, or sheets of different shades of colour. This entails considerable time and expense, as each sheet separately has to pass in review before the eye of the operative. It is, however, a process which can hardly be simplified. On going over a paper-mill manufacturing high-class papers, and seeing the enormous staff of operatives engaged in this work, and the attention that has to be bestowed upon it, the absolute necessity of care in the making department, to produce paper as clean and as regular in shade and quality as possible, will be fully appreciated.

3. *Remarks on the Economy of a Paper-mill.*—The great bulk of the power required in a paper-mill is consumed in driving the engines for reducing the raw material into pulp. A pair of engines, capable of turning out about 250 lbs. of paper daily, will exert about 40 HP. on an average; but of course this amount will vary considerably in different mills with the nature of the material used, and the mode of treatment.

The total HP. consumed in motive-power in a paper-mill for all purposes may be estimated roughly at 300 HP. per 1,000 tons of paper per annum for an engine-sized mill; and 380 HP. for the same amount for a tub-sized mill. About 75 per cent. of this power, on an average, is consumed in driving the pulping engines.

As regards the primary motive-power to be employed in driving the mill, a paper-maker will naturally prefer water to steam. The water available may, however, only be sufficient to supply part of the power required, or it may fail during the drier seasons of the year; so that steam-power has generally to be provided equal to the water-power used, as a reserve in case of emergencies.

Water-power can be utilized in two ways through the medium of waterwheels, or else of turbines. The latter have proved in every way superior to waterwheels, especially for the transmission of high powers and quick speeds. They give a greater efficiency than waterwheels, are more easily housed, and for the production of high speeds, as they revolve at a very rapid rate, do away with the multiplication of heavy gearing necessary to change a low speed to a high one.

The best mode of transmitting power to the engines, whether by toothed gearing or by belting, will depend greatly upon the arrangement of the mill. In transmitting high powers, which have to be suddenly applied, belts as a rule are not so efficacious as toothed gearing in producing a constant velocity-ratio, owing to their liability to stretch and slip, irrespective of the extra expense entailed by the heavy wear and tear. But in the reduction of raw material to pulp, especially in the beating-engine, absolute regularity in the transmission of power is not so essential as the smooth and steady bearing of the roll on the plate. There is always a certain amount of jar and vibration in the motion produced through the direct action of toothed wheels, which is entirely overcome by the use of belts; besides, the tension of the belt over the pulleys produces a steady downward bearing of the roll on the plate, which is not the case with gearing. Toothed-gearing will answer best for the transmission of the motive power in bulk to the driving-shaft; but for the production of a uniformly divided pulp, it should be subdivided to the engines through the medium of belting.

In a large paper-mill driven entirely by steam-power, only about one-half of the coal used in raising steam is consumed in the driving-power, the other half being employed in the manufacturing departments for boiling, heating and drying purposes. Where water-power is adopted wholly or in part, by far the larger portion of coal is consumed in producing steam for the manufacture pure and simple; and it is here where economy should be directed as far as possible in the saving of coal. From 4 to 6 or 7 lbs. of coal are required to produce 1 lb. of paper, in a mill employing steam-power alone, depending on the class of mill.

In connection with the above, the following considerations will arise:—whether the greatest economy will be effected by the use of condensing-engines for the main-driving, and the production of separate steam for manufacturing purposes and the low-pressure workings; or by the use of non-condensing engines, and employing the exhaust steam from these as back-pressure steam for the use of the mill. By the adoption of a condensing-engine a considerable increase of power is obtained, without extra expenditure of fuel, by utilizing the full-pressure of the steam. But in a paper-mill, where so much heat is required for drying and heating purposes, it becomes of importance not only to utilize the full pressure of the steam produced, but the total amount of heat contained in it. Now by far the greater portion of heat in steam of any temperature and pressure is present in the form of latent heat, which is not given out until it is condensed. This latent heat amounts to 537 thermal units, and is the quantity of heat required to convert 1 lb. of water at boiling point to steam at the same temperature. A comparatively small amount of heat is necessary to raise the steam to a higher temperature and pressure.

Hence, almost the whole amount of heat present in the steam used in driving a condensing-engine is wasted; and the result resolves itself into the practical question as to whether the greatest economy in expenditure of fuel is obtained by the separate production of the steam for drying and heating purposes, or by working with a non-condensing-engine and using the exhaust steam for manufacturing purposes. In a well-conducted mill, whichever plan is adopted, all waste steam is utilized in heating the water for the boilers, &c.

As it is of the greatest importance that the paper-machine should be maintained at a uniformly steady and unvarying rate of speed, to ensure regularity in the weight and thickness of the paper, it is not only convenient but necessary that each machine should have a motive-power of its own, at the same time driving the stuff-chest and pumps. The steam-engines used for this purpose should be strong, well-built, and provided with a large fly-wheel and a good quick-acting governor, to reduce to a minimum all variations of speed. The drying-cylinders of the making-machine form an efficient and convenient condenser for the driving-engine, but it is questionable whether it is not better to provide a steam-engine with a separate condenser, and to lose the heat that escapes with the condensed steam. The heat of the drying-cylinders has frequently to be increased or diminished to suit the requirements of the paper, and this alteration in the condensing power of the engine would be detrimental to a uniform and regular rate of speed. The advisability of allowing the steam to pass from one drying-cylinder to another, in place of providing a separate steam-pipe to each, has already been mentioned. The full amount of heat contained in the condensing steam will be utilized, when the number of cylinders is such that all the steam can be condensed in them.[1]

Made at first entirely from the waste products of textile manufactories and clothing, the production of paper has now far exceeded the possible supply of these materials, and other fibrous products of the vegetable kingdom have been brought in to supply the want. Esparto, straw and wood are the three most important of these, but even their supply is not sufficient for the ever-increasing demand, and great efforts are now being made in different parts of the world to discover natural products which shall yield, with profit and success, material suitable for the manufacture of paper.

A great impetus has lately been given to the trade in wood-pulp, through the discovery of one or two processes for obtaining the pure fibre from wood cheaply and satisfactorily, and some large factories have recently been established in Sweden and other places, where the supply of wood is ready at hand. India is the home of a variety of fibrous plants, and experiments have been set on foot there to ascertain if any can be made available as a raw material. To encourage these experiments, the Indian Government has offered a reward to the inventor of a process which will economically and profitably produce the desired result.

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[1] "Appareils servant à la Fabrication du Papier," § 5, Sécherie. By M. L. Vigreux of Vienna. Paris, 1881.

The total number of paper-mills in existence is three thousand nine hundred and eighty-five, producing annually 1,055,000 tons of paper made from all classes of materials. Ninety thousand men, and twice that number of women and children are employed.[1] The capital embarked in the industry exceeds £62,000,000 sterling.

The consumption of this enormous quantity of paper, is divided in the following manner:—

	Per Annum. Million lbs.
Daily papers	490
Weekly, Monthly, &c.	380
Books	150
Printing	1,020
Schools	190
Public offices	160
Letters	220
Account-books, &c.	120
Wall-paper	450
Papier-maché, &c.	205
Total	2,365

Wheels for railway-wagons are now made of compressed paper instead of iron. The dome of the new Palais de Justice at Brussels is all of paper. Flour barrels are made of it in the United States, one factory at Iowa turning out 1,600 barrels daily, from 5 tons of paper, each barrel taking 6 lbs.

In conclusion, the Author wishes to express his thanks to Mr. F. Logie Pirie, of the firm of Messrs. Alexander Pirie and Sons, for valuable advice in the preparation of this Paper.

The communication is accompanied by numerous drawings and diagrams, from which Plates 6 and 7, and the figures in the text, have been prepared.

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[1] "Mulhall's Dictionary of Statistics," by M. G. Mulhall, F.S.S. London, 1884.

[Appendix.

APPENDIX.

TABLE SHOWING LOSSES ON RAW MATERIAL DURING the VARIOUS OPERATIONS.

The percentage of free moisture in rags varies from 3 per cent. to 6 per cent.

Rags.	Moisture.	Sorting.	Cutting.	Boiling.	Breaking and Bleaching.	Total.	Grand Total.	Cost Price per cwt.			Actual Cost for Waste.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	£.	s.	d.	£.	s.	d.
English New Pieces	3	0·5	1·0	3·0	12·5	15·15	18·91	1	5	0	1	10	9
French „	3	0·5	1·2	7·3	13·2	19·60	23·33	1	4	0	1	11	3
German „	3	0·5	1·2	11·8	11·6	22·03	25·64	1	3	0	1	10	11
No. 1 Cotton . .	3	0·9	2·0	3·0	12·4	15·04	19·96	1	1	0	1	6	3
No. 2 „ . .	4	1·2	2·5	7·94	14·8	21·60	27·49	0	17	0	1	3	5
No. 3 „ . .	4	1·5	3·8	11·16	13·6	23·26	30·16	0	15	0	1	1	5
No. 4 „ . .	5	2·0	4·0	14·3	17·4	29·27	36·76	0	10	0	0	15	9
New Soft Tabs .	4	0·5	1·0	3·0	8·4	11·14	15·96	1	5	0	1	9	9
Best White Tabs.	4	1·0	4·0	8·6	16·6	23·78	30·45	1	2	6	1	12	4
Grey Tabs . .	4	0·8	2·5	15·1	9·8	23·46	28·92	0	19	0	1	6	8
Unbleached Cotton	4	0·8	2·0	12·28	13·4	24·05	29·11	0	19	0	1	6	9
White Moleskins.	4	0·8	2·0	11·00	8·9	18·99	24·38	0	19	0	1	5	1
Drab „ .	4	1·0	2·0	13·00	10·1	21·79	27·15	0	15	0	1	0	7
Jean Cuttings .	4	1·0	2·0	17·4	6·1	22·48	27·79	0	16	0	1	2	2
Green Cords . .	5	1·0	2·5	21·3	8·0	27·64	33·60	0	11	0	0	16	6
Old Blue Cotton .	5	1·5	3·8	14·4	9·2	22·32	30·06	0	13	0	0	18	7
Shirtings . . .	4	0·5	2·6	11·6	12·4	22·59	27·98	0	15	6	1	1	6
S.P.F.F.F. Linen.	4	0·8	2·0	8·5	11·8	19·38	24·74	1	5	0	1	13	2
S.P.F.F. „ .	5	1·3	2·4	11·1	12·8	22·51	29·08	1	0	0	1	8	2
S.P.F. „ .	6	1·8	2·7	17·36	19·6	33·62	40·37	0	16	6	1	7	8
No. 1 Linen . .	4	0·5	2·0	6·8	7·4	13·77	19·28	1	4	0	1	9	8
No. 2 „ . .	5	0·8	2·4	14·5	8·2	21·54	27·83	1	0	0	1	7	8
No. 3 „ . .	6	1·0	2·7	19·15	9·8	27·11	34·00	0	16	0	1	4	3
No. 1 Russian L.	6	1·5	2·4	18·7	10·0	26·90	33·94	0	17	0	1	5	9
No. 4 „ .	6	3·0	5·0	30·0	20·7	44·53	51·94	0	13	0	1	7	0
Linen Duck Clippings . . .	4	0·5	2·0	15·4	9·6	23·58	28·46	1	5	0	1	14	11
Linen Threads .	4	0·5	2·0	12·5	12·6	23·55	28·43	1	5	0	1	14	11
New Blue Linen.	4	0·8	2·0	15·1	13·9	26·90	31·76	1	0	0	1	9	3
Unbleached Linen	4	0·5	2·0	19·2	16·0	32·14	36·47	0	19	0	1	9	10

Esparto.	Boiling.	Breaking and Bleaching.	Total.	Cost Price per Ton.			Actual Cost for Waste per Ton.			Remarks.
	Per cent.	Per cent.	Per cent.	£.	s.	d.	£.	s.	d.	Lbs. Per cwt.
Spanish . . .	39·24	11·00	45·92	8	7	6	15	10	2	15·2 Caustic soda 9 Bleaching powder
African . . .	46·00	17·18	55·27	7	0	0	15	13	2	20 Caustic soda 9 Bleaching powder

(*Paper No. 1999.*)

"On Hauling out and Launching Vessels Sideways."

By Murray Jackson, late Chief Engineer of the Danube Steam Navigation Company.

The slip-ways at the ship-building yard of the Imperial and Royal Danube Steam Navigation Company, at Alt-Ofen in Hungary, extend along the water-side for a distance of nearly 650 feet, and have a depth inland of about 280 feet. The slip-ways are arranged in three separate groups, A, B, and C, Plate 8, Fig. 1, each of which can be used at discretion for building or repairing the steamers, about eighteen to twenty barges and other vessels belonging to the Company finding accommodation at one time. The number of new boats built and launched yearly seldom exceeds sixteen to eighteen, while sixty steamers and barges are annually drawn out of the water for examination and repair. This is effected by hauling the vessels broadside out of the water by chains connected with geared winches and blocks (Fig. 2), the weight of the hulls being taken up by cradles, placed under water at the end of slipways to receive them. In the drawing the height of the water, which varies in the course of the year 10 to 12 feet, is shown at 8 feet above datum, which is rather under the average, the slip-ways with this height of water being submerged about 69 feet at the ends. There is no current. It will be seen that the formation of the ground is artificial, having been raised at the back in the neighbourhood of the wall to 25 feet 10 inches above datum, in order to get the necessary incline, the level of that part of the yard immediately adjacent being the same as that of the roadway, E. Only the lower portions of the slipways are permanent, and partially laid on rough stonework, the length of this part being about 150 feet. That part of the ways situated on the higher level can be removed after the vessels are hauled up and relaid when required for launching. In case, however, a vessel remains only a short time ashore, the ways are not removed. Fig. 1 shows the general disposition of the whole arrangement, the eight slipways of the central portion being usually reserved for the larger steamers, which are hauled up broadside on by means of the four winches and blocks; the upper and lower portions have each seven slip-ways, which are worked indirectly by the same winches, by suitable sheaved blocks and other arrangements. Along the whole length of the ground runs a line of rails, shown at F F, provided with lorries, for facilitating the manipulation of the chain used in hauling. These chains are $\frac{7}{8}$ inch diameter, best quality, short-linked, that used for the slings (round the hulls) being of the same description, but $1\frac{1}{8}$ inch diameter.

The motive power is derived from a 10-HP. engine used at the same time for working punching and shearing machines and other machinery. Fig. 2 shows the mechanical arrangements employed on a somewhat enlarged scale. The lower barge (Fig. 1) is represented in the act of coming in contact with the submerged cradle, prior to the hauling out commencing. The second barge is being hauled up the slip-ways, and the third barge is represented as having been made clear of the cradle, and placed fair on cross-blocks of wood, ready for examination and repair. The speed at which the vessels are hauled out varies from 1 to $1\frac{1}{4}$ feet per minute, the motion being continuous and exceedingly smooth throughout. With regard to the class of vessels thus dealt with, the barges have mostly a length of 180 to 190 feet, with 24 feet beam and $8\frac{1}{2}$ feet depth, having a displacement without cargo of 120 tons. These barges have been built in recent years entirely of steel. The largest steamers are 220 feet to 250 feet in length, with 25 feet to $27\frac{1}{2}$ feet beam and 10 feet depth at the sides, having a light displacement of 440 to 460 tons. Two small monitors, belonging to Government, are likewise hauled out from time to time. These, on account of their weight being distributed over a shorter length, are more trying to the ways, but no difficulty has arisen either in hauling them out or re-launching them. The winches, four in number, are shown in Fig. 2, and are double-geared 9 to 1; they are driven by a line of shafting in the rear in connection with the engine. The slings, after being firmly secured to the hulls, are attached to four pairs of blocks, the lower or movable one running on wheels on the incline on a way laid down for it. The number of pulleys in each block is three. By means of the mechanical arrangements described the power gained is very great, and has been in all cases more than sufficient for the work to be done, the cost of labour being reduced at the same time to a minimum.

The communication is accompanied by a series of drawings, from which Plate 8 has been compiled.

(*Paper No. 2016.*)

"Pumping-Machinery for Draining a portion of the Marshes near Fondi, Southern Italy."

By Thomas Richard Guppy, M. Inst. C.E.

In the year 1882 the Author's firm undertook to construct and erect for the Provincial Board of Public Works of Caserta, two complete sets of steam-engines with centrifugal pumps, guaranteed to raise 20,500 gallons of water per minute to a height of 7 feet 8 inches, for the purpose of draining part of the marshes near Fondi, and thus reclaim the land for cultivation, and at the same time render the neighbourhood more healthful. This large extent of constantly submerged land was useless for cultivation, and the stagnant water made the whole district a most unhealthy one, as it produced pestilential exhalations during the summer months, which infected and poisoned the atmosphere for miles around. On this account the peasants could not reside on the spot, but lived in villages built on high ground a considerable distance away from these marshes, and came down to their work every morning and returned home in the evening before sunset. Even with these precautions it is scarcely possible to escape the effects of the bad air, and the people who frequent these districts are sallow, subject to low intermittent fevers, and are not in a really fit state of health to perform hard work. The value of the land for these reasons was naturally much depreciated, and in many cases the owners allowed their property to be confiscated rather than submit to pay taxes on ground which brought them in no revenue.

The marshes, which are now drained, are situated between a range of hills on the north, and the small lake of Fondi on the south, and are formed by a considerable depression of ground, which permitted the rain-water to collect. The lake derives its supply of water from springs at the base of these hills, and the water is brought down by the Canale d'Acqua Chiara, the overflow discharging itself into the sea on the opposite side.

The mode of draining these marshes has been to cut large canals parallel to each other, intersecting the space between by small canals that collect and bring the water down to the pumping station. These large canals vary in width from 6 to 15 feet, their total length being upwards of 12 miles; the small canals are about 4 feet wide and over 6 miles long altogether. Several of these canals extend down to the sea, and they are then provided with sluices which are closed when the tide rises.

The average annual rainfall is 32 inches, but as a large volume of water collects from the surrounding country, it has been found from experience that it requires at least six days to pump up the rainwater that falls in twenty-four hours. The pumps generally commence working after the first heavy rains in October, and continue running, as required, throughout the winter up to the end of April. On starting the pumps in the autumn, when the land requires to be tilled, both engines and pumps have to work for the first fifteen days, twenty-four hours per day, until the water is reduced to a certain level; for the next fifteen days they work twelve hours per day, and after this one engine and pump is generally sufficient to keep the land dry, except in the wet season, when, if necessary, both engines are employed to pump away the extra rainfall. All the water pumped up is discharged into the Canale d'Acqua Chiara, and flows through the Lake of Fondi into the sea. It may be stated that the quantity of water lifted by the pumps has been ascertained to be about 27,000 gallons per minute.

The area of land drained is about 12,000 acres, of which at least 10,000 acres are at present kept dry and under cultivation. The land reclaimed is a rich alluvial soil, mixed with clay, admirably suited for raising all kinds of cereal crops, especially Indian corn. Since it has been drained and cultivated there are already signs of a decided improvement, splendid crops are being raised, and the proprietors, far from demurring to pay the land-tax, now willingly submit to an extra tax for the drainage of their property, which lets freely at £5 per acre.

Of course it is too soon to form an opinion whether the salutary conditions of the neighbourhood have been bettered. It will always be a difficult matter to do this, as sufferers from intermittent fevers are liable to a return of the attack at different periods, and it is not easy to fix upon a starting-point from which to make comparisons. Doubtless in time beneficial results will be felt, and a gradual decrease of sickness observed.

It may be mentioned that it is proposed shortly to put up another set of engines to drain the other parts of these marshes, which lie to the west. A project is also under consideration at Rome to adopt similar sets of pumping machinery to drain the marshy land round that city at Isola Sacra, Polda Maccarese, Polda d'Ostia, all situated in the district known as the Agro Romano.

Buildings and Machinery.—The house erected to contain the pumping machinery is situated close to the Canale d'Acqua Chiara. Owing to the nature of the soil it was necessary, in order to ensure solid foundations, to protect them from being undermined by the water in the lateral canals, to drive in piles on which broad foundations were laid and walls built. On each side of this building are the lateral canals that bring the water from the marshes to the suction-pipes of the pumps, whence it is lifted and discharged into the large reservoir constructed in masonry, which is in communication with the Canale d'Acqua Chiara, so that the water flows away direct to the lake. The reservoir has sluices that can be closed should the water in the Canale d'Acqua Chiara rise higher than the level of the water in the reservoir.

There are two horizontal boilers, each 18 feet long and 4 feet 11 inches in diameter, with an internal flue 2 feet 7½ inches in diameter, in which are placed five conical tubes; at the back end of the boiler there are thirty-one iron tubes. Each boiler has a heating surface of 376½ square feet, and a fire-grate area of 12 square feet. The working pressure is 70 lbs. per square inch, and as a single boiler is sufficient for supplying the steam to both engines, the second is kept in reserve.

The two horizontal steam-engines that drive the centrifugal pumps have one cylinder each, of 13⅜ inches in diameter, with 15¾ inches in length of stroke, fitted with variable expansion valves, cutting off steam at 0·175 of the stroke. The condensers and air-pumps are placed behind the cylinders, being bolted to the same bed-plate, and are worked direct by the piston-rods of the cylinders. In case the suction-pipes of the air-pumps should get choked with weeds, an extra injection cock is provided, connected with the casing of the centrifugal pump, so that the air-pump may still obtain its supply of water for condensing. This cock can also be used to form a vacuum in the cases of the centrifugal pumps, should the ejectors get out of order. The small donkey-engine for feeding the boilers draws water from the condenser when the engines are working, or from the canal when they are at rest.

The two large centrifugal pumps are coupled to the mainshaft of each engine. The outer casing of these pumps is 7 feet 7 inches in diameter, and cast in two pieces, the lower part being fixed to one side of the bed-plate of the engine, and has a large flange on the upper side, on to which the upper half is bolted. The lateral suction-pipes are also bolted to the sides of this casing by flanges, which admit of their being easily dismounted to examine the disk inside, remove weeds, &c. The suction-pipes have no foot-valves, and the discharge-pipe a hinged valve, which remains closed when the pumps are not at work. The disks are 3 feet 11½ inches in diameter, with a central web having six long and six short blades on each side. The spindle of the pump is of Bessemer steel, with a brass casing, and lignum vitæ bearings. Each pump is supplied with an ejector for forming the vacuum in the suction-pipe before starting.

Results obtained at the Official Trials.—In December, 1882, the following experiments were made in the presence of the Italian Government engineers appointed to inspect the machinery, and to ascertain if it fulfilled the conditions of the contract. At the two trials both engines were set in motion with steam supplied from one boiler, and were kept running for twelve hours. On the first occasion the pumps ran at one hundred and thirty revolutions per minute, the pressure of steam in the boilers was 70 lbs. per square inch, cut-off at 0·175 of stroke, the vacuum was 24½ inches, and 24,700 gallons of water were raised per minute, the lift being 6 feet 6¾ inches, and the consumption of coal 2¾ cwts. per hour.

On the next trial the experiment was continued with a lift of 5 feet 8 inches, when, with the same number of revolutions, the pumps raised 27,300 gallons of water per minute, with a consumption of 2½ cwts. of coal per hour. The quantity of water raised was on an average 47¼ per cent. of the indicated HP. with a mean consumption of 6·12 lbs. of coal per HP. per hour.

The Paper is accompanied by a map and two drawings, from which Plate 9 has been prepared.

(*Paper No. 2023.*)

"Notes on Compressed Air and Machinery for Utilizing it."

By John Kraft, M. Inst. C.E.

Compressed air was first used on a large scale at the Mont Cenis tunnel. All the machinery, tools, and other mechanical appliances for this great work were made at the Cockerill Works, Seraing, and their construction was specially confided to the Author. At that period he made, in conjunction with the late Mr. Sommeiller, extensive experiments to serve as a guide to their labours; and, but for the lamented death of his colleague, they would have been published. At present many documents are missing, and the subject is no longer new, but the general results are sufficiently well established to allow of their being given in a highly condensed form.[1]

Compression.

The compression of air is accompanied by the production of heat, and if the compressing apparatus is so disposed as to prevent either loss or accession of heat, the air obeys Poisson's law.

If p_1 be the initial pressure of the air in kilograms per square metre.
v_1 its volume corresponding to the initial pressure.
p_2 the pressure to which the air is compressed.
v_2 the volume occupied under that pressure, and
$K = 1 \cdot 41$, coefficient resulting from experiments, then

$$\frac{p_2}{p_1} = \left(\frac{v_1}{v}\right)^K.$$

This formula corresponds to Poisson's law. The diagram for this law is shown in Fig. 1 by the line —·—·—·—.

If the compressing apparatus is so constructed that the air is deprived of the heat produced by its compression as fast as this heat is developed, the air being thus kept at a constant temperature, follows Boyle's[1] law. This law can be expressed thus

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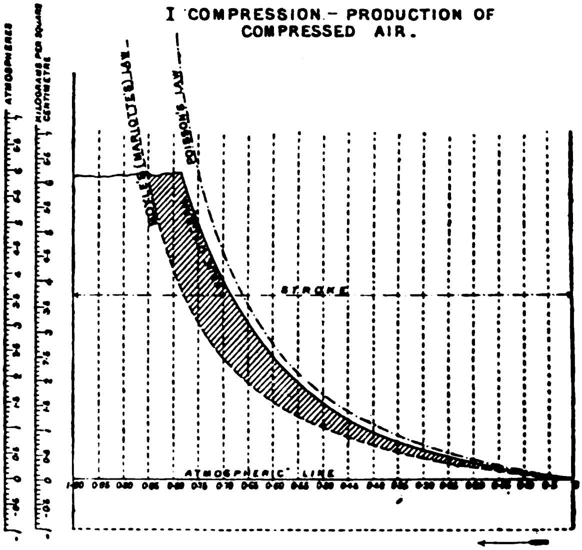
[1] A more detailed account of these experiments will be found in the "Revue Universelle des Mines," vol. vi., 1879, p. 301.

$$\frac{p_2}{p_1} = \frac{v_1}{v_2},$$

and the line - - - - - - corresponds to its diagram.

Fig. 1.



That which takes place in the compressor is something intermediate between these two extreme cases. The heat is not entirely preserved by nor entirely withdrawn from the air.

The line ——— Fig. 1, gives the true diagram taken from the compressors.

The shaded part shows the work accomplished by the piston, beyond what is required by Boyle's law. This work is generally lost, because the air in the reservoirs cools, and returns gradually to its initial temperature.

Utilization of Compressed Air.

When air is used in an engine as motive power, the air cools as it expands, and produces work. If the engine is so made as to allow of neither loss nor gain of heat, the air observes Poisson's law.

The lines - - - - - Fig. 2, show the diagram for this law, according as the air is utilized at pressures of 5 or 4 times the atmospheric pressure.

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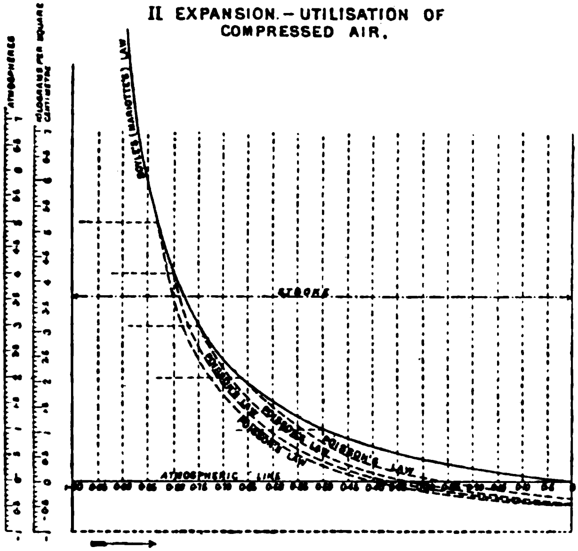
[1] Marriotte's in the original.

If the air could be kept constantly at the same temperature, by heating it during its expansion, the law followed by the air would be that of Boyle, shown by the line ——— Fig. 2. The difference between these two diagrams shows the true loss.

Fig. 2.


II EXPANSION.—UTILISATION OF COMPRESSED AIR.

These diagrams show also in the particular case they represent, that the air taken at 5 atmospheres effective or 6 atmospheres absolute pressure, with cut-off at $\frac{1}{6}$ of the stroke, would reach the external pressure of 1 atmosphere at the end of the stroke, if the temperature remained constant and the air consequently obeyed Boyle's law. But such is not the case; the air cools, and its pressure diminishes more rapidly than Boyle's law would require. It obeys Poisson's law, and the atmospheric pressure is reached at a point distant from the end of the stroke by 0·40 of its length. Taking the air at 5 atmospheres effective or 6 atmospheres absolute pressure, the external pressure is reached at 0·65 of the stroke.

This circumstance limits the degree of expansion that can be utilized in air-engines.

From what precedes it will be seen that the production of compressed air is attended with loss of work, due to its heating, and that the utilization of this air in an air-engine entails a further loss of power by refrigeration. This last loss is rendered still more important by the limit put to expansion. The expansion is moreover limited by a considerable decrease in temperature. This decrease of temperature is so great that an engine working for any length of time is often stopped by the freezing of the moisture contained in the air, and consequent obstruction of the passages. There were at the Mont Cenis works air-engines working expansively, whose cylinders had to be warmed externally, to prevent the engines being stopped by freezing. One of these cases was rather amusing. In one part of the tunnel there was a very small ventilating-fan, worked by a small compressed-air engine. For some time the fan worked perfectly, then it would stop; the engine was frozen. The engine once at rest, there was no longer production of cold; after some time it thawed and started again on its own account. When a tin-can, full of water, was placed in the current of air escaping from an air-engine the water froze rapidly, the ice thus obtained being opaque like alabaster. The cylinders of the engines were soon coated with hoar frost.

The compressing machinery used at Mont Cenis is well known, and need not be referred to. In subsequent examples, while retaining the principle of the water-piston the compressors have been notably improved. A type which the Author considers as one of the best, if not the best, is that of Messrs. François and Dubois. Mr. François was employed under the Author at the time of the Mont Cenis works, and went afterwards to Mr. Sommeiller. His associate, Mr. Dubois, is manager of the great Marihaye Collieries at Seraing, where the use of compressed air was first introduced, and where it is still practised on a very large scale. Both these gentlemen have had opportunities for studying the matter thoroughly. Numerous experiments made in past years with the Sommeiller compressor gave results which were never inferior to 90 per cent. of useful effect. The slight loss of 10 per cent. was mainly caused by the heating of the walls of the apparatus, along which the aspirated air must pass, by the absorption by the water contained in the apparatus of a small quantity of air, and by the opening of the valves. The two water-columns which constituted the piston in the Sommeiller compressor, offered a certain liquid mass, limiting the rate at which the apparatus could work, and this liquid mass became, after some time, impregnated with air which formed a kind of dead space.

Messrs. François and Dubois retained Sommeiller's principle of having water in the interior of the compressor, but they limited the quantity to what was absolutely necessary for cooling the air, and filling up dead spaces. They, moreover, connected the suction-valves on both sides of the piston, so that the opening of the one was synchronous with the closing of the other. This disposition allows of a high speed, without a higher increase of temperature than in the Sommeiller compressor, of which it is in some sort a continuation. The useful effect is always at least 90 per cent., and 93 per cent. has been obtained at fifty revolutions per minute, which is certainly a very good result. In the Belgian mines this compressor is used almost exclusively, and it has often been called in to replace other compressors on less successful systems.

In the case of the St. Gothard tunnel works the compressors were at first sought to be of small size, to run at a high speed, and to be cooled externally. There was something contradictory in this. When the compressor has a short stroke and runs fast, the air makes only a very short stay in it, and the heat developed cannot pass through the walls of the apparatus with sufficient rapidity to be absorbed by the external current of cooling water. Moreover, without water in the apparatus there are unavoidable dead spaces, which however small reduce the useful effect. It must be observed that though these dead spaces cause a loss in the volume of air produced, there is no loss of mechanical power, this last being always in proportion to the volume of air really compressed.[1] These compressors could not give a high useful effect. The Author understands that, later on, a small valve was added, for injecting water into the compressor—a significant fact.

The above-mentioned report gives (p. 84) the following results:—

Pressure in Atmospheres.	Time in Minutes.	Revolutions observed.	Useful Effect.
6 to 7	15	960	0·78
7 „ 8	16	1,022	0·74
8 „ 9	18	1,150	0·66
9 „ 10	20	1,280	0·59

It is more than probable, though the Author cannot speak authoritatively as to the fact, that the small injection-valve was fitted when these observations were made.

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[1] Details of these compressors will be found in the Quarterly Report of the Swiss Federal Council of the St. Gothard No. 16 of 1876; also in the Minutes of Proceedings Inst. C.E., vol. xlii., p. 238.

The employment of turbines at the south entrance of the St. Gothard tunnel at Airolo, where the water falls from a height of 540 feet, has always occasioned surprise. It necessarily entailed running at a very high speed, which had to be reduced by spur-gearing, in order to obtain a velocity more or less suitable for the reciprocating movement of the compressors. The occasion seems to have been more suitable for using water-pressure engines, working the compressors directly. Properly constructed water-pressure engines are very efficient in such cases. At the Modane end of the Mont Cenis tunnel such a motor was employed working a compressor, and another giving power to a workshop. Both operated admirably with a head of 246 feet.

The preceding facts are all in favour of moderate pressures, and are further confirmed by experience. There is nothing to be gained by using air at more than 3, 4, or at the outside 5 atmospheres, except where the air must be led to great distances. Then everything is to be gained by transporting the air in small volumes, thus avoiding expensive piping, and loss by friction in pipes. In this question the balance of advantages and disadvantages must be calculated for each particular case.

It might be expected that the losses of power incurred, in the production and the utilization of compressed air, should cause it to be rejected as a motive power. But in many cases it is not so. Thus for instance, for a series of cranes, these machines working only at intervals. Where steam is used, enormous losses are caused by condensation in the pipes and expansion, and condensation can scarcely be used in the engines. Whereas on the other hand, compressed air can be produced by high-class engines consuming very little coal. In this way the loss incurred by employing air may be compensated for. For a set of cranes like those at the Cockerill Works, Seraing (Plate 10), or at Portsmouth Dockyard, steam cannot compete with air. The principal rival of compressed air is water, and there are many cases where water is to be preferred. For cranes placed in the open air in cold countries, the great impediment to the use of water is frost. The Author is of opinion that in this as in many other cases, "each thing has its place." There are some cases where water, and others where air, is to be preferred.

Thus in the Seraing engine-works air is used, and in the steel-works, water; each being in its appropriate place. For the installation of a number of cranes in the open air, along a quay-wall, the Author thinks air is preferable, as in the case of Portsmouth Dockyard.

APPENDIX I.

Number and principal dimensions of the air-compressors and compressed-air engines working cranes in the Engine Works of the Société Cockerill, Seraing (Plate 10).

A. One air-compressing engine with two working cylinders.

Diameter of steam-cylinders	350 millimetres.
,, air-cylinders	350 ,,
Stroke of air- and steam-cylinders	750 ,,
Revolutions per minute	26

B. Two air-reservoirs.

Length	11 metres.
Diameter	2 ,,
Maximum pressure in reservoirs	5 atmospheres.
Diameter of piping	50 millimetres.
Total capacity of air-reservoirs	83·73 cubic metres.

C. 40-ton travelling-crane with two double-cylinder engines.

Diameter of cylinders	115 millimetres.
Stroke ,, ,, ...	180 ,,

D. Three 4-ton swivel-cranes with one double-cylinder engine

Diameter of cylinders	115 millimetres.
Stroke ,, ,, ...	180 ,,

E. Single-cylinder engine working pump for hydraulic press used for forcing wheels on axles.

Diameter of cylinder	160 millimetres.
Stroke ,, ,, ...	180 ,,

f. Twelve 12-ton swivel-cranes with double-cylinder engines.

G. Two 15-ton swivel-cranes with double-cylinder engines.

Diameter of cylinders	115 millimetres.
Stroke ,, ,, ...	180 ,,

l. Air-cocks fitted on main pipe of locomotive-shed for supplying the 40-ton traveller.

LIFTING-APPARATUS NOT WORKED BY COMPRESSED AIR.

G′. 15-ton swivel-crane driven from overhead shaft.

H. Travelling-crane worked by hand, for flywheel-floor I.

J. Travelling crane worked by hand, running from end to end of small erecting-shop.

h. Two small hand-cranes for locomotive erecting-shop.

The compressing-engine stops automatically when the pressure reaches 75 lbs. per square inch, and in like manner begins working when it falls below that figure. The air-cranes differ in no way from those worked by steam so far as their engines are concerned, and all can be worked with a pressure of 45 lbs. per square inch.

Besides the above-mentioned cranes an overhead traveller worked by air has been fitted in the Foundry Extension. This crane carries a reservoir with 90 lbs. pressure, and is worked at 40 lbs. by means of a reducing valve.

The establishment of air-cranes in these works dates from 1854.

APPENDIX II.

AIR-COMPRESSING PLANT at PORTSMOUTH DOCKYARD.

One pair of inverted direct-acting engines (not compound), having cylinders 24-inches diameter, 4 feet stroke; variable expansion gear ranging from a cut-off of $\frac{1}{15}$ to $\frac{1}{3}$; 80 lbs. steam; 50 revolutions per minute; driven by means of spur gear 2 : 1; two pairs of water displacement air-compressing pumps, having horizontal barrels 24 inches diameter, 3 feet stroke, making 25 revolutions per minute, double-acting, air at 60 lbs. pressure. Four air-vessels 10 feet diameter, 28 feet 5 inches in height, with flat bottoms and hemispherical tops; cubic contents 7,553 cubic feet, connected by a 12-inch pipe. Diameter of mains, 15, 12, 9, 8, 6 inches, led through subways to various machines.

(*Paper No. 2036.*)

"The Barmouth Waterworks."

By THOMAS ROBERTS, Assoc. M. Inst. C.E.

BARMOUTH is an ancient seaport in Merionethshire, situate on the River Mawddach, where it empties itself into Cardigan Bay.

The opening of the Cambrian Railway in 1867, and the extension of the Great Western line from Ruabon, brought the place within easy reach of the manufacturing centres of England, and it rapidly became a favourite watering-place.

A local board was formed in 1872, and works of water-supply and sewerage were immediately projected. After examining various sources of water-supply, what was known as the Ceilwart scheme was adopted. The water is derived from a spring 295 feet above datum (datum being 100 feet below B.M. on Gilbertson's doorstep High Street), and from the Ceilwart River, the intake therefrom being 312 feet above datum. The spring produces with hardly any variation 38,704 gallons, and after careful gauging, the minimum flow down the river was found to be 77,000 gallons per day, giving a minimum quantity of 115,704 gallons per day. The catchment basin available above the intended impounding-reservoir has an area of 238 acres, on the slopes of the Llawllech range of mountains, the geological formation being Cambrian sandstone intermixed with beds of slate-rock. There are no houses or cultivated land above the impounding reservoir, consequently the water finds its way into the river with very little contamination.

The average rainfall for a series of years is 60·875 inches per annum. Assuming one-third (say 20 inches) of the rainfall to find its way into the stream, the 238 acres would produce 107,992,500 gallons per annum, or 295,869 gallons per day. The population during the bathing season is about 3,000, and at 20 gallons per head per day, 60,000 gallons per day would be required. Having regard to the large rainfall, it is considered that storage for one hundred days would be sufficient, which would give 6,000,000 gallons, or 96,000 cubic feet, as the capacity of the impounding reservoir.

The land for the reservoir, easement of pipes, and water rights, was purchased at a cost of £1,000, exclusive of legal and other expenses. The works, as designed, comprise an impounding reservoir for 6,000,000 gallons, straining-tanks, filter-beds, service-reservoir to hold 93,796 gallons, with conduit-pipes capable of delivering 187,542 gallons per day; and they have been carried out with the exception of the impounding-reservoir, straining-tanks, and filter-beds. It was considered that the spring, supplemented from the stream, would, for some years, afford an adequate supply, and consequently, the impounding-reservoir, straining-tanks, and filters were not carried out. For ten years this proved ample for all purposes; but the drought of 1884 has demonstrated that it will be necessary to make the impounding-reservoir. A plan of the town showing the line of piping is given in Plate 11.

The intake No. 1 from the spring is 3 feet square, built in 9-inch brickwork in cement, on concrete foundation 9 inches thick, with a depth of 2 feet between the bottom and the invert of the overflow-pipe.

Connection with the reservoir is effected by means of a 4-inch cast-iron pipe with a rose on the inlet end. A sluice-valve is placed on the connecting-pipe. By closing the valve and observing the time it takes to fill the tank, the quantity of water flowing from the spring can at any time be ascertained. Intake No. 2 from the stream is, by means of a separating-weir, designed to convey the water when the stream is at its ordinary height, to the service reservoir; but during sudden floods, in consequence of the increased velocity over the weir, the flood-water shoots over the mouth of the inlet-pipe, and passes down the ordinary channel. This prevents the access of turbid water to the service-reservoir. An equilibrium ball-valve is fitted to the discharge-end of the conduit-pipe from the stream, adjusted to close when the reservoir is full.

The site of the service-reservoir, immediately below the spring, is on drift (marl and clay), intermixed with large boulders. The excavation was taken out to a depth of 18 inches below the finished level of the floor, the depth at one end being 14 feet 6 inches, at the other 18 inches. At the south-western corner there was a hollow scooped out by floods to a depth of about 3 feet below the level of excavation. This was cleared to the solid, and filled with rubble composed of large flat stones well grouted. The bottom was then covered with a layer of cement concrete, varying in thickness from 12 to 15 inches, and extending 12 inches beyond the footings of the walls. The walls are coursed rubble in hydraulic mortar, lined on the inside with 4½ inch brickwork in cement, with a cement core of at least ¾ inch thick between the brick lining and the masonry. The masonry was carried up simultaneously, and grouted every 2 feet; the mortar being composed of one part of hydraulic lime and one part of sand. The roof is formed of three semicircular arches turned in 9-inch brickwork on 18 inches by 3 feet brick piers, the piers being connected a little below springing line by flat arches turned in 9-inch work. The bottom is paved with bricks on edge, laid in cement. Ventilation is secured by perforated slate slabs 3 feet × 2 feet, fixed at each end of the roof arches, except where the door is placed; in which case the upper part of the door is perforated to correspond with the slate slab ventilator at the other end.

A cleaning outlet and overflow, communicating with the stream, are provided, and when necessary to empty the reservoir for cleaning or repairing, a pipe is provided, giving direct communication between the stream and the main conduit pipe. Access to the inside is obtained by a door at the end of one of the roof-arches and a wrought-iron ladder. The concrete is composed of one part Portland cement, one of sand, and four of shingle from the beach; the cement being capable of bearing a tensile strain of 350 lbs. per square inch after seven days' immersion in water; the sand was sharp, and the shingle clean and free from seaweed. First quality pressed Staffordshire blue bricks have been used for lining, paving, and piers, to springing line of roof, the remainder being sound common bricks. The walls are 6 feet 6 inches thick at the bottom, and 3 feet 6 inches at the springing of roof-arches. They have been designed to give a factor of safety of five against hydrostatic pressure when the reservoir is full.

The main conduit pipes are of cast-iron, with turned and bored joints on the straight portions, and spigot-and-faucet leaded joints on the curved parts. The service pipes are lap-welded galvanized iron. Between the service-reservoir and the centre of the town they are 5 inches internal diameter, the submains being 4 inches and 3 inches. The whole are coated with Dr. Angus Smith's patent solution, and have been tested to 600 feet head of water, equal to 265·8 lbs. to the square inch. The service pipes vary from 1 inch to ⅜ inch internal diameter. All pipes have been laid with their upper sides 2 feet 6 inches below the surface of ground. Air-valves and cleansing outlets have been placed at convenient intervals on the main pipes and in the town. Fire-hydrants have been fixed at regular intervals of about 40 yards. The valves throughout have all their working parts of gunmetal, and all surface-boxes are surrounded with Syenite sett paving.

The main pipes were made large enough to deliver 187,542 gallons per day of twelve hours, equal to 20 gallons per head per day for a population of 9,377, or about three times the present requirements, with the view of providing a good margin for the future extension of the town.

The cost of construction was—

	£.	s.	d.
Intake-works and service-reservoir	1,103	10	0
Main and service-pipes, valves and hydrants .	1,652	10	0
	2,756	0	0

The intake works and service reservoir were carried out in the year 1881; the main and service-pipes were laid in 1874 with temporary intakes.

The Paper is accompanied by five sheets of tracings, one of which is given in Plate 11; also by a detailed schedule of prices.

(*Paper No. 2038.*)

"The Results of some Independent Engine-Tests."

By John George Mair, M. Inst. C.E.

Since the Author wrote the Paper "On the Independent Testing of Steam-engines, and the Measurement of Heat used,"[1] he has made several additional independent tests of different types of engines, under varied conditions of working, and ventures to think that the results that may be deduced from them will be found interesting, and of practical value, not only to engineers, but also to users of steam-power. The economy of the steam-engine, and its special design and adaptation to the ever-varying purposes of its requirements, are questions of such paramount importance to all manufacturing and commercial nations, that every effort should be made to determine independently the efficiency of engines and of boilers, as only by this method of testing can the best design of engine, and the most efficient distribution of steam, be determined.

Independent testing admits of balance sheets, or debtor and creditor accounts, being made, and Sir Frederick Bramwell well described their value when he stated at the meeting of the British Association at Montreal, 1884,[2] that "an engineer with a balance sheet in his hand is able to say, I am debtor to the fuel for so many heat-units, how on the credit side of my account do I discharge that debt?"

The present system, of comparing the power given out by an engine with the amount of coal burnt in the fire-box of a boiler, is so obviously absurd that it is to be hoped the time is not far distant when the power will only be compared with the heat absorbed in producing it. This was pointed out by the Author in his previous Paper, where he gave in detail the method of testing, and the manner in which the heat used can be measured. Since that Paper was written, the works of Mr. Hirn and the late Mr. Hallauer have again been criticised by Dr. Zeuner,[3] who has raised several objections to their mode of treating the subject, the principal ones being as follow:—

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[1] Minutes of Proceedings Inst. C.E., vol. lxx., p. 313.

[2] Engineering, vol. xxxviii., p. 212.

[3] "Der Civil Ingenieur," 1882, heft v.

1. That owing to the violent eddying motion of the steam during admission, and at the point of cut-off, the indicator diagram does not give the pressures with sufficient accuracy during these periods.

2. That the water left in the cylinder and clearances after the exhaust is closed almost entirely accounts for the exchanges of heat, and the loss by re-evaporation during exhaust R c, which Mr. Hirn attributes to the action of the cylinder walls.

3. That the two methods adopted by Messrs. Hirn and Hallauer for finding R c, or the loss during exhaust, are no check on each other.

The remaining objections of Dr. Zeuner are minor points of detail, and in no way affect the principles adopted.

These strictures have been fully replied to by Messrs. Hirn and Hallauer,[1] and also by Professor Grashof,[2] of Carlsruhe, who strongly favours their views. Dr. Zeuner has, with his usual clearness, given fundamental formulas for calculating the exchanges of heat between the cylinder-walls and the working steam, and has extended his researches to those special cases where the steam is superheated, not only at the point of cut-off, but up to the end of the stroke. These formulas agree, except in some slight details, with those given by the Author.

The three principal objections of Dr. Zeuner will now be dealt with:—

It is evident that if the steam-ports of an engine be quickly closed,[3] the whole mass of the steam in the cylinder, which has been flowing in with great velocity, will be suddenly stopped, and therefore, owing to the eddying motions then set up, the pressure will not be uniform throughout the mass, and a certain period of time must elapse before the kinetic energy of motion is transformed into heat, and the pressure in the cylinder is correctly shown by an indicator; and if the engine is running very fast, it may even be presumed that the piston reaches the end of its stroke before a state of thermal equilibrium is arrived at in the cylinder. But the errors made by accepting an indicator diagram, as not only giving the correct pressures, but also (with saturated steam) the temperature due to the pressure, cannot be of sufficient magnitude to in any way nullify the general principles of engine-testing, and the measurement of the heat-exchanges. With steam much wire-drawn, that is, where the pressure in the cylinder is much lower than the pressure in the boiler or steam-pipe, allowance should perhaps be made, but any neglect in taking this correction into consideration, cannot seriously influence the action of the sides of the cylinder.

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[1] "Réfutations d'une seconde critique de M. G. Zeuner," par G. A. Hirn et O. Hallauer. 1883.

[2] "Zeitschrift des Vereins deutscher Ingenieur," 1883.

[3] "The Steam-Engine considered as a Heat Engine." By James H. Cotterill, M.A., 1878, p. 243.

The second of Dr. Zeuner's objections is of more importance, and it is to be regretted that, with present appliances, it is not possible practically to ascertain the quantity of water left in the clearance after exhaust, to meet the in-flowing steam at the commencement of the stroke; it cannot, however, be a large amount, and certainly not in an engine that is well steam-jacketed and has compression; but even if water does exist, the loss during exhaust R *c* remains practically the same as if there were no water.

This is well shown by Messrs. Hirn and Hallauer in their second refutation[1] of the criticisms, where they give various calculations, showing that if a large quantity of water is assumed to remain after the exhaust-valve closes, the exchanges of heat are not materially altered.[2]

In the Author's opinion, it is only in the most inferior design of engine that it is possible for any appreciable amount of water to be retained in the clearance; and even then no error of magnitude could be made if the steam is supposed to contain, at the point of compression, the same amount of water suspended in it as it had at the moment of exhaust.

Many experiments were carried out by Mr. James Simpson, M. Inst. C.E., with the 150-HP. engines at the Chelsea and Lambeth Waterworks, to ascertain if water was left in the clearances, but in no case was any found; it should be remarked, however, that the engines had their cylinders thoroughly steam-jacketed.

The principal remaining objection of Dr. Zeuner is undoubtedly correct, as can be seen by the Author's previous Paper; that R *c*, the loss during exhaust, should have the same value, whether it is calculated from the heat supplied from the boiler, or from that rejected and found in the air-pump discharge.

Trials L, M.—These were made with a single-cylinder beam rotative engine, the cylinder being 32 inches in diameter by 5 feet 6 inches length of stroke. The engine works two double-acting pumps direct from the beam, and forces water to a reservoir, without any services being taken off the main, so that the work can be kept perfectly uniform. The cylinder sides and base are jacketed with boiler steam, and the distribution is effected by main and expansion slides at the top and bottom, worked by eccentrics in the usual manner, and the cut-off is adjusted by hand. There is a jet-condenser, but unfortunately from its position the air-pump discharge, and consequently the rejected heat, could not be measured.

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[1] "Réfutations d'une seconde critique de M. G. Zeuner," par G. A. Hirn et O. Hallauer. 1883.

[2] "Étude pratique sur l'échappement et la compression de la vapeur dans les Machines," par M. Hallauer. 1883.

Trials N, O.—These were also made with a single-cylinder beam rotative engine, similar to the last described, taking its steam from the same nest of boilers. The cylinder is 27 inches in diameter by 6 feet length of stroke, having a smaller sweep than the last, so that a comparative trial could be made, to ascertain the relative efficiency at a lower rate of expansion.

Trial P.—This was carried out on a Bull engine, with cylinder 68 inches diameter and 10 feet length of stroke, driving direct a 45-inch plunger; it forces water to a height varying from 40 to 55 feet. The valves and gear are of the usual Cornish pattern, and the cylinder and base are steam-jacketed.

Trials Q, R.—These trials were made with a Woolf beam rotative engine, working a double-acting high-lift pump, the cylinders with their covers and bases being steam-jacketed; the cylinders are 29 inches in diameter by 5 feet 5 inches length of stroke, and 47½ inches in diameter by 8-feet length of stroke; the steam is distributed by slides, at the top and at the bottom of each cylinder, with cut-off plates at the back, adjustable by hand; the low-pressure cylinder has separate double-beat exhaust-valves, worked by cams.

Trials S, T, U.—These trials were also undertaken with a Woolf beam rotative engine, working a high-lift pump on each side of the beam. The cylinders with their covers and bases are steam-jacketed, being 22 inches in diameter by 4 feet 7 inches length of stroke, and 37 inches in diameter by 6 feet 6 inches length of stroke. The distribution of steam is effected by separate slides at the top and at the bottom of each cylinder, having adjustable cut-off plates at the back. The exhaust-valves are double-beat, worked by cams.

These engines, with the exception of the Bull (which was made by Messrs. Harvey, of Hayle), were constructed by Messrs. Simpson and Co., so that naturally a general uniformity exists in their design.

They have all been tested according to the methods described in the previous Paper, and the formulas there given have been employed for determining the amount of heat used, their efficiency, and for calculating the exchanges of heat between the cylinder walls and the working steam. For convenience and ease of reference these formulas are repeated in the Appendix.

To reliably compare trials of any kind, they must be made under similar conditions of working in every way, and this principle is specially applicable to engines, where even a slight difference in design and of the distribution of steam influences the results. Comparisons therefore are effected with great difficulty, and definite conclusions are not readily arrived at.

In Table VI. will be found the number of thermal units used by the engines per indicated HP. per minute, when the feed-water is delivered into the boilers at the temperature of the air-pump discharge, and also the amount of coal that would be consumed if its evaporative efficiency were 11,000 thermal units per lb.; but for comparisons the feed should be reduced to a uniform temperature, and as before, 32° Fahrenheit will be adopted, which is the same as is used by Messrs. Hirn and Hallauer. To eliminate the effect of back pressure in the cylinder during exhaust, owing to wire-drawing in the valve-ports and passages, and inefficient arrangement of condenser, air-pump, &c., is difficult. Professor Cotterill has proposed the adoption of a fictitious temperature for the condenser of 125° Fahrenheit, equivalent to 2 lbs. on the square inch:[1] but Mr. Hirn and the late Mr. Hallauer compare their results, on the supposition that a perfect vacuum of 1 atmosphere acts on the piston during exhaust, and they increase the indicated power of the engines to be compared on this basis, calling the power so obtained "absolute horse-power."

In the Author's opinion the proposal of Professor Cotterill is the best; but as a back-pressure of 1 lb. has been obtained, the fictitious temperature adopted ought not to be greater than 100°. A perfect vacuum cannot be reached, and to base comparisons on it gives an undue advantage to an engine that is working at a high rate of expansion, over one that carries the steam further through the stroke. For instance, if two engines are working under exactly similar conditions, except that one engine has a mean pressure of 40 lbs. per square inch, while the other has only 20 lbs. (owing to a higher rate of expansion), and say both have a back-pressure of 3 lbs. during exhaust, then the absolute power calculated on the assumption of a perfect vacuum, equal to an atmosphere, existing under the piston in both engines, would cause an increase of 7½ per cent. in the first case, and of 15 per cent. in the latter, to its evident advantage.

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[1] "The Steam-Engine considered as a Heat Engine." By James H. Cotterill, M.A., 1878, p. 277.

Mr. Isherwood, Chief Engineer United States Navy, compares the results of trials made with the machinery of the steam-yacht "Siesta,"[1] by taking as effective work on the pistons, not only the back-pressure during exhaust, due to the imperfect vacuum, but also the loss that occurred during the transference of the steam from the high- to the low-pressure cylinder.

In the previous Paper there is a statement of the amount of heat used per total horse-power, which, it will be remembered, is the power that would be given out if a vacuum were produced in the cylinder corresponding to the temperature of the condenser. In Table VII. of this Paper are given the total horse-powers and also the absolute horse-powers, so that any form of comparison can be readily made.

SINGLE-CYLINDER ENGINES.

Trials L, M, N, O.—These trials may be fairly compared together, as the engines are similar in design, and work at about the same boiler-pressure and piston-speed. They were supplied with steam from the same boilers, and under uniform conditions as regards grate and heating surface, length of steam-main, &c.

The principal results of the trial marked A, single cylinder (see previous Paper),[2] are added in Table I., and grouped with these trials, although the conditions that engine worked under are not quite so favourable for comparison, as the boiler-pressure was rather lower, and the piston-speed less.

This set of trials comprises rates of expansion from 1·95, with wire-drawn steam, to 6·85, and also one trial with the steam-jackets shut off. They are placed in order according to the number of expansions.

Trial A was fully described in the previous Paper.

Trial L was made with 4·33 expansions, and the jacket at work.

Trial M was carried out with the same engine as Trial L, but the jackets were shut off, all other circumstances being practically alike, as in the other trials; but it will be noted that to get the same indicated power, the number of expansions had to be reduced from 4·33 to 3·84.

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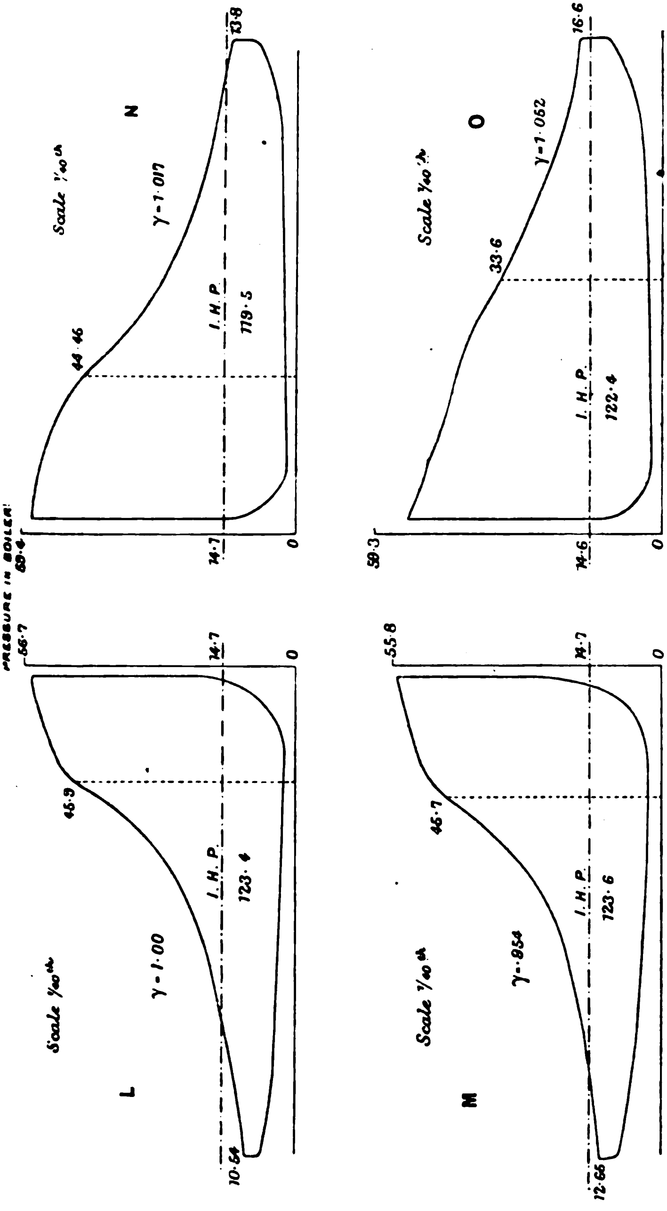
[1] "Report made to Bureau of Steam Engineering, by B. F. Isherwood on Machinery of the 'Siesta.'" Government Printing Office, Washington, 1883.

[2] Minutes of Proceedings Inst. C.E., vol. lxx., p. 321.



SINGLE CYLINDER ENGINES.

TABLE I.

Number of Trial.	Number of Expansions.	Indicated Horse-Power.	Absolute Boiler-Pressure.	Percentage of Water Present in Cylinder at Cut-off.	Percentage of Q Lost by B c.	T U per Indicated HP per Minute from Temperature of 32° Fahr.
			lbs.			
A	6·85	101·79	48·00	43·8	19·1	429·1
L	4·33	123·40	56·70	29·3	17·1	430·0
M[1]	3·84	123·60	55·80	37·0	19·1	515·9
N	3·16	119·50	59·40	22·0	12·4	416·3
O[2]	1·95	122·40	59·30	14·8	10·4	460·7

[1] No steam passed through the jackets. [2] Steam very much wire-drawn.

Trial N was made with the jackets on; but as the cylinder, as before stated, was smaller compared with the power exerted, the steam had to be carried further through the stroke, and only 3·16 expansions could be made when the engine was indicating almost the same power.

Trial O.—On this trial, the expansion-plates were set to cut-off at half-stroke, and the steam had therefore to be wire-drawn to obtain the same power. The jackets were at work, with full boiler-pressure of 59·3 lbs. absolute, the steam at cut-off in the cylinder being only 33·6 lbs. The results of these trials fully confirm others that have been made with single-cylinder engines under varying rates of expansion. On referring to the heat used per indicated HP., it will be seen that the most economic ratio of expansion was 3·16 times, but if there had been a perfect vacuum of 1 atmosphere under the piston on each trial 4·33 would have been the most efficient ratio.

Mr. Emery, of the United States Navy, made a very valuable series of experiments with the engines of the "Rush," "Dexter," "Dallas," &c., and deduced from the non-compound engine experiments that the formula $1 + \frac{P}{22}$ (where P is the absolute boiler-pressure) presents the most economical ratio of expansion.[1] This formula gives 3·5 expansions with an absolute boiler-pressure of about 55 lbs., which closely agrees with the best results, as seen in Table I.

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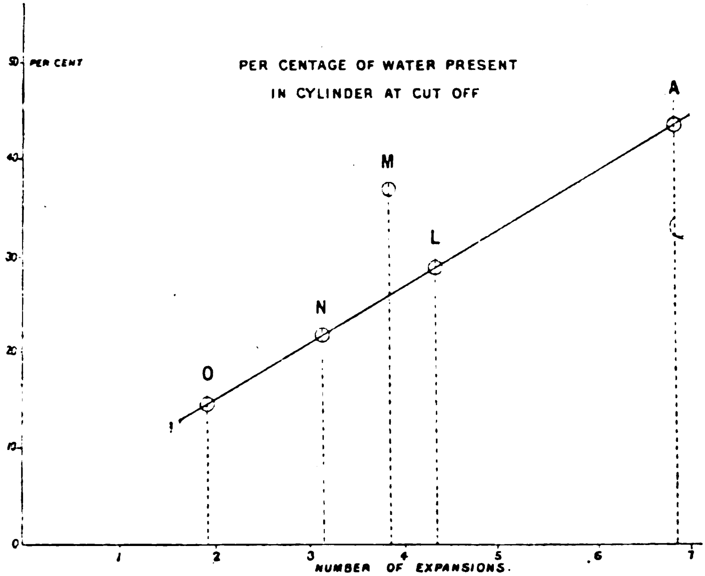
[1] "The Steam Engine considered as a Heat Engine." By James H. Cotterill, M.A., 1878, p. 302.

Theoretically, the greater the expansion the greater the economy; but as the action of the cylinder-walls also increases at the same time, only by careful practical trials can the limit be found, beyond which, if the expansion is increased, the efficiency is reduced.

It is interesting to observe the rate at which the condensation on admission increases with the number of expansions, and this is shown graphically in Fig. 1. This increase of condensation has also been pointed out by Mr. D. K. Clark, in his Paper on "The Behaviour of Steam during Expansion."[1]

Fig. 1.



The effect of steam-jackets can be seen by comparing trials L and M, and it will be noted that when the jacket was shut off (trial M), the initial condensation increased from 29 to 37 per cent., and at the same time the loss R *c* increased from 17 to 19 per cent., while the amount of heat used per I.HP. was about 20 per cent. greater.

With the Woolf engine (see trials B and C in the previous Paper), shutting off the jackets increased the amount of water present at cut-off from 40·8 to 51·1 per cent., and the loss during exhaust from 3·1 to 24·4 per cent., while the heat used per indicated HP. was raised from 338·8 T.U. to 519·5 T.U., or about 53 per cent.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 287.

These results clearly show the advantage derived from steam-jackets, and why economy is obtained from their use. An interesting trial was made at Flensburg,[1] by Mr. Hansen, on an unjacketed engine, working at an expansion of 8·55 times. In this case, through the absence of the jacket, combined with the great variation of temperature that took place, about 61 per cent. of the steam that passed through the cylinder was condensed during admission, and the loss during exhaust R *c* was 27 per cent. It appears therefore that, even in a well jacketed single-cylinder, expansion must be limited to secure the maximum of economy; and if the engine has no jacket the rate of expansion ought to be still lower. To obtain the benefit of a high rate of expansion recourse must be had to the compound principle, as then the range of temperature is divided between two or more cylinders, and consequently the action of the sides reduced.

BULL ENGINE.

Trial P.—On this trial, which was of twelve hours duration, 42·7 feet was the average head in the main; and taking the quantity of water lifted as equal to the full displacement of the plunger, only 62·1 per cent. of the indicated power was given out in work. Had the engine pumped against the full head of 55 feet, for which the pole was weighted, 80·2 per cent. of the indicated power would have been utilized. This clearly shows how unfitted a Cornish engine is for pumping into a main in which there is a variation of the water-pressure, as with the same amount of steam as used in the trial, the water could have been lifted over 50 feet in place of only 42·7 feet.[2] The length of stroke was carefully measured, and averaged 9·862 feet. Before the trial the engine was examined, under the direction of Mr. T. Hack, M. Inst. C.E., and found to be in thorough order, and the valves and pistons tight and free from leakage. The boilers supplied steam only to the engine, so that the feed was readily measured, the jackets were disconnected, and the condensation from them discharged into measured buckets. The air-pump discharge was gauged, and the engine worked at as high a rate of expansion as was safe. Every precaution was taken to render the trial thoroughly reliable, and to obtain the best result. For convenience, in the Tables the indoor- or steam-stroke is detailed under the heading of the high-pressure cylinder, and the outdoor- or exhaust-stroke under the low-pressure cylinder. The action of the cylinder-walls is most marked, and although only 1¾ expansions were made, and the engine had the jacket fully at work, the water present at cut-off was 16·7 per cent. Evaporation took place throughout the remainder of the stroke, reducing the amount of water present at the end of the indoor-stroke to 14·7 per cent. During the outdoor-stroke condensation was taking place, which caused Qb_1 to be a negative quantity, and at the moment of exhaust, 22·8 per cent. of water was present, the loss Rc being 19·2 per cent. This engine used 30 per cent. more heat than the Cornish engine (see trial K in the previous Paper). The absence of a beam prevents a high rate of expansion in a Bull engine, as there is no mass to receive the initial blow of the steam,[1] and although so few expansions were made on the trial, the piston came in on the indoor-stroke with so great a velocity that it would have been dangerous to work at an earlier cut-

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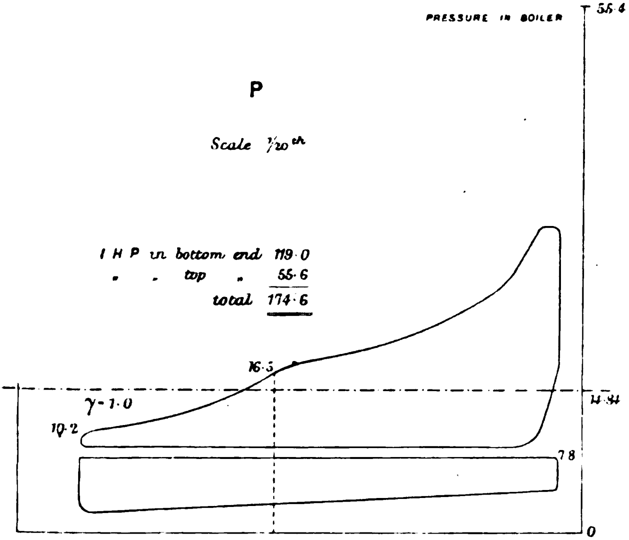
[1] Engineering, vol. xxxiv., p. 493.

[2] Science Lectures at South Kensington, vol. i., p. 154, 1878. F. J. Bramwell "On the Steam-Engine."



SINGLE ACTING BULL ENGINE.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 68.

off. Taking 11,000 T.U. as the value practically obtainable with the best Welsh coal, and allowing 2½ per cent. for slip in the pump, the duty of the engine would be 54·5 million foot-lbs. raised 1 foot high per cwt. of coal, if pumping to the full height forced by the weights in the pole case. The amount of steam passing through the jacket was almost the same as with the Cornish engine before referred to, and the bad duty is due to the low rate of expansion, absence of jacketing or cleading round the equilibrium pipes, and want of compression to fill the clearance spaces, which are very large, and also to the bad vacuum.

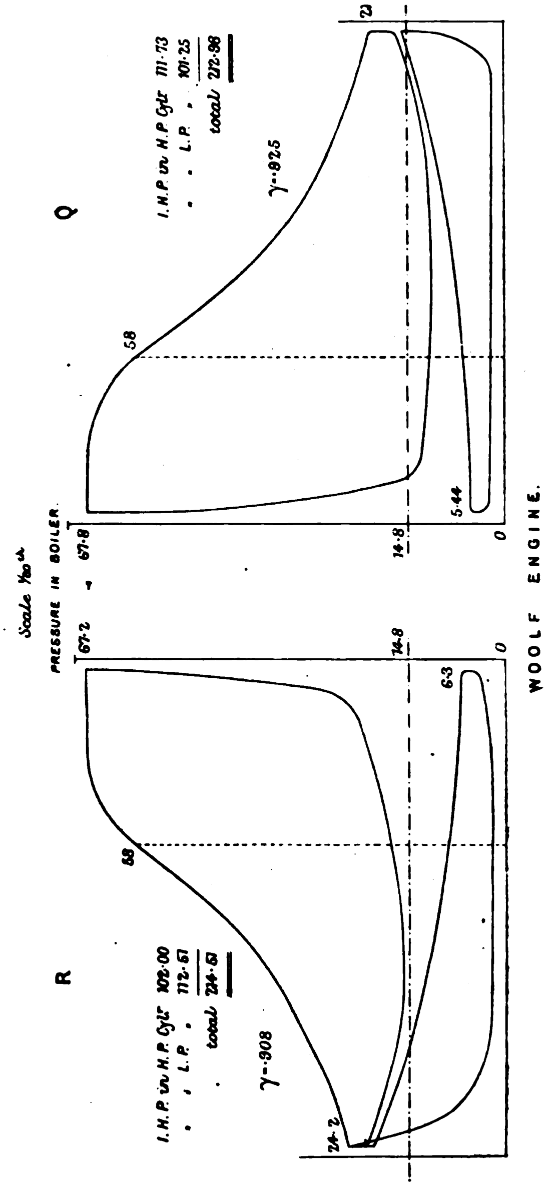
WOOLF ENGINES.

Trials Q, R.—These were made with an engine, having cut-off valves on both the high- and low-pressure cylinders. Six trials were carried out; only two will, however, be described and their details given. The first (Q) was made with a late cut-off in the low-pressure cylinder, and the exhaust-valves set to give a moderate compression; the other (R) was with an early cut-off in the low-pressure cylinder, and a heavy compression (see diagrams). On the first trial 13·4 per cent. of the total feed passed through the jackets, and on the other 11 per cent. To show how great is the influence of the amount of heat passing through the jacket on the steam consumption, the following Table is given:—

Per Cent. of Total Feed through Jacket.	T. U. per I.HP. per Minute.	Lbs. Dry Steam per I.HP. per Hour.
11·0	324·2	16·58
12·3	316·4	16·18
13·4	306·3	15·65

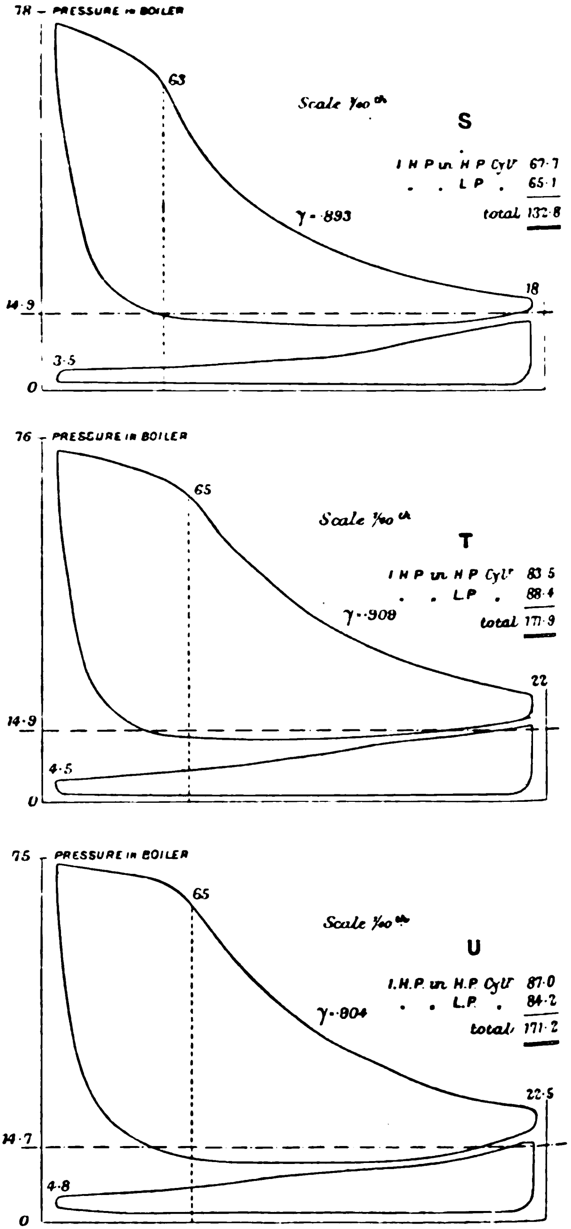
It must be remarked, however, that these results are no doubt slightly influenced by the difference in the distribution of the steam; but, in the Author's opinion, such influence is very small compared with the advantage obtained from the additional amount of heat passing through the jackets. Had not careful trials been made it would have been supposed from the diagrams that the engine was working far more economically than only 5·8 per cent. better on trial Q than on trial R.

Trials S, T, U.—These trials are very interesting, as, owing to a separate jacket-boiler, the pressure, and consequently the temperature of steam in the jackets, could be varied from that of the working steam, and as a larger pump was fixed after the first trial (S) the engine worked at different rates of expansion. It will be observed that, whether the jacket-steam was at the temperature of the working steam or from 27° to 31° above it,


Q
I.H.P in H.P Cylr 111·73
" " L.P. " 101·25
total 212·98
γ=·925
58
23
5·44
67·8
14·8
0
Scale 1/80th
PRESSURE IN BOILER = 67·8
67·2
14·8
0
6·3
58
R
I.H.P in H.P Cylr 102·00
" L.P. " 112·51
total 214·51
γ=·908
24·2

WOOLF ENGINE.

the results were practically equal; and also that the engine gave



WOOLF ENGINE.

almost the same result at 12½ expansions as it did at 16½ when working under similar conditions, except as to mean pressure. The percentage of the total heat through the engine given up from the jackets was, however, naturally larger when the greater number of expansions were made, so that in all probability the lower rate of expansion would have proved more economical if the heat from the jackets could have been kept in the same proportion in both cases. By comparing the result of the best trial (U) it will be seen that, although it approaches very closely, it does not come quite up to the economy obtained with the compound engine (see trial J in the previous Paper), fitted with an intermediate receiver, on the system of Mr. E. A. Cowper, M. Inst. C.E.

Referring to Table VI., where the disposal of heat through the engine is given, it will be seen that even with the best results only about 15 per cent. of the heat delivered from the boilers and passing through the engine is utilized, while 85 per cent. is wasted.

To ascertain the greatest saving that could be effected on the 85 per cent., the theoretical efficiency must be calculated from the formula $\frac{T_1 - T_2}{T_1}$, where T_1 and T_2 are the limits between which the engine works, measured from the zero of absolute temperature; and working this out for 60 lbs. pressure in the boiler and a temperature of 100° in the condenser, the efficiency is 27 per cent., so that the loss in a perfect engine would be 73 per cent. of the heat supplied; and even if the boiler pressure were raised to 150 lbs., and the condenser kept at 100°, 68 per cent. must be lost, and it should be borne in mind that the greater the limits of temperature between which an engine works the more difficult it is to approach the theoretic efficiency. The relative or true efficiency of the engines tested is given in Table VII., where it is expressed as a percentage of the theoretical efficiency actually obtained, the maximum being about 55 per cent. With these facts in view, how important it is to take every advantage that can be gained from steam-jacketing, efficient distribution of steam, and perfect arrangements for condensing. In the Appendix to this Paper will be found the results of the trials, the symbols and their equivalents, the formulas grouped together, and a Table, which has been prepared by Mr. T. H. Houghton, Assoc. M. Inst. C.E., giving the weights of steam calculated from the formula of Dr. Zeuner[1] for pressures rising by tenths of a lb., from 1 lb. to 19·9 lbs. on the square inch.

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[1] Minutes of Proceedings Inst. C.E., vol. lxx., p. 327.

APPENDIX.

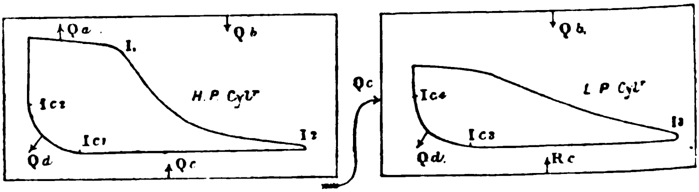
The symbols used in the formulas are as follow :—

H = total heat of steam measured from 32° Fahrenheit;
h = T. U. necessary to raise the temperature of 1 lb. of water from 32° Fahrenheit to a temperature t;
L = latent heat of vaporization;
ρ = internal heat of vaporization;
M = weight of steam per stroke through cylinder in lbs.;
M_P = „ priming water per stroke through cylinder; Table IV.
M_J = „ jacket steam „ (total);
M_{JH} = „ „ „ in H.-P. cylinder;
M_{JL} = „ „ „ in L.-P. „
Π = injection water per stroke in lbs.;
f = temperature of air-pump discharge; Table II.
i = „ injection water;
Q = quantity of heat in T. U. per stroke; Tables IV., V.
W = work expressed in T. U. „ ; Table III.
I = internal heat; Table III.
R_e = exhaust waste through cooling action of condenser;
R_H = radiation from H.-P. cylinder; Table V.
R_L = „ L.-P. „

The index γ of the constant $P V^\gamma$ is given on the indicator diagrams in the Paper.

The following diagrams (Figs. 2) show the relative positions of the different values of Q and I during the stroke, and also the direction in which the transfer of heat generally takes place between the working steam and the cylinder walls.

FIGS. 2.



The numbers appended to the formulas refer to the numbers in the previous Paper:—

1. Q = Heat passing through engine per stroke,

$$Q = M H + M_P h + M_J L.$$

Q_1 = Heat retained in condensed steam,

$$Q_1 = (M + M_P)(f - 32).$$

Q_2 = Heat absorbed by injection water,

$$Q_2 = \Pi (f - i).$$

2. To check the heat Q through the engine by the rejected heat,

$$Q = Q_1 + Q_2 + W_i + R$$

I = The internal heat of a mixture of steam and water, where m = the mass, and x = the percentage of steam in the mass,

$$I = m\,(h + x\,\rho).$$

5a. Q_a = The heat given up during admission,

$$Q_a = Q - M_J\,L + I_{c2} - I_1 - W_a.$$

7, 8. Q_b = The heat absorbed during expansion in H. P. cylinder,

Q_{b1} = " " " " L. P. "

$$Q_b = I_2 - I_1 + W_b$$

$$Q_{b1} = I_3 - (I_2 - I_{c1} + I_{c4} + W_e) + W_{b1}.$$

6. Q_d = The heat given up during compression in H. P. cylinder,

Q_{d1} = " " " " L. P. "

$$Q_d = I_{c1} - I_{c2} + W_d$$

$$Q_{d1} = I_{c3} - I_{c4} + W_{d1}.$$

3, 4. The equilibrium of the thermal exchanges between the steam and the cylinder walls is expressed by the relations—

For the H.-P. cylinder—

$$Q_a + Q_d + M_{JH}\,L = Q_b + Q_c + R$$

For the L.-P. cylinder—

$$Q_{d1} + Q_e + M_{JL}\,L = Q_{b1} + R_e + R_L.$$

And from these equations (3 and 4) can be found the values of Q_c and also R_c, or they can be found as follows—

10.

$$Q_c = Q - W_{iH} - W_e - I_2 + I_{c1} - R_H$$

$$R_e = Q - W_i - W_{e1} - I_3 + I_{c3} - R.$$

TABLE II.—DATA.

—	L	M	N	O	P	Q	R	S	T	U
Date of trial	July 1882		March 1883		July 1884	October 1882		January–February 1884.		
Type of engine	Single cylinder Beam.		Single cylinder Beam		Bull Double Strokes.	Woolf Beam		Woolf Beam.		
Revolutions per minute	20·31	20·26	20·0	20·0	12·35	17·783	17·775	28·305	28·16	27·48
Volume of H.-P. cylinder in cubic feet	30·377		23·61		Steam Side. 245·7	24·491		11·877		
„ „ „ clearance in cubic feet	0·558		0·57		13·4	0·504		0·406		
„ L.-P. cylinder „	..		..		Exhaust Side. 248·72	97·814		48·2		
„ „ „ clearance „	..		..		33·26	1·904		1·656		
Volume at end of admission „	7·140	8·051	7·65	12·37	160·8	8·341	9·549	3·02	3·732	3·791
Boiler pressure over atmosphere in lbs. per sq. inch	42·0	41·22	44·7	44·7	40·65	53·0	52·4	63·25	61·25	60·25
Absolute steam-pressure in jackets „ „ „	56·68	55·8	59·4	59·3	55·4	67·84	67·18	78·0	76·0	116·0
Feed to boilers per stroke	lb. 1·13787	lb. 1·35589	lb. 1·0824	lb. 1·2253	lb. 7·6748	lb. 1·65171	lb. 1·75231	lb. 0·62836	lb. 0·80619	lb. 0·81257
Steam-jacket condensation per stroke M_J	0·05555	none	0·0528	0·0528	0·3158	0·22211	0·19281	0·07110	0·07838	0·08286
Weight of steam and water shut in H.-P. clearance, $m c$	0·03241	0·04835	0·0197	0·0231	Steam Side. 0·7887	0·09952	0·17358	0·09254	0·08380	0·08600
„ „ „ „ L.-P. „ $m c_1$	..	..	..	..	Exhaust Side. 0·2827	0·06871	0·18042	0·02333	0·02333	0·02275
Temperature of injection water t	58°	58°	57°	57°	68·6°	60·5°	60·0°	45·7°	45·75°	45·5°
„ air-pump discharge f	90°	100°	90°	91°	112·6°	107·36°	109·2°	76·72°	81·31°	80·02°
Injection water per stroke in lbs. n	..	..	..	..	170·0	29·63	30·29	17·77	19·87	21·25

TABLE III.—WORK and INTERNAL HEAT.

——	—	L	M	N	O		P	Q	R	S	T	U
The following are expressed in T. U. per stroke—												
Absolute work of full admission	W_a	64·4	70·2	68·0	96·9	Steam side.	602·7	91·8	106·0	34·5	44·1	45·4
" " total expansion in H.-P. cylinder	W_b	90·4	92·6	72·6	50·6		236·5	105·1	105·1	53·0	57·6	56·9
Work of expulsion from H.-P. cylinder . .	W_c	20·1	24·2	10·9	14·3		381·4	51·8	72·2	27·1	30·4	26·6
" compression in " " . .	W_d	4·9	8·2	1·9	2·4		45·8	11·0	16·4	9·3	8·0	8·0
Absolute work in L.-P. " . .	W_{b1}	..	..	..	..	Exh. side.	351·2	162·9	203·2	63·4	81·5	80·2
Work of expulsion from " " . .	W_{c1}	..	..	..	..		155·4	32·1	35·3	12·8	12·8	13·3
" compression in " " .	W_{d1}	..	..	..	..		3·3	9·1	32·6	1·4	1·4	1·4
Indicated work in H.-P. cylinder . . .	W_i	129·8	130·4	127·8	130·8		412·0	134·1	122·5	51·1	63·3	67·7
" " L.-P. "	W_{iL}	..	..	..	..		192·5	121·7	135·2	49·2	67·1	65·5
Internal heat of mixture at cut off . . .	I_1	937·5	1089·1	947·3	1143·7		7548·0	1350·7	1541·7	543·3	688·3	696·8
" " H.-P. exhaust .	I_2	956·8	1158·8	959·9	1132·6		7633·1	1466·5	1669·7	622·0	759·2	773·0
" " L.-P. " .	I_3	..	..	..	..		6550·5	1573·2	1812·0	529·6	675·4	712·6
" at commencement of compression in H.-P. cylinder . .	$I^c{}_1$	32·8	49·0	16·7	20·8		843·1	106·8	187·5	99·7	90·2	92·6
" at end of do. do. . . .	I	33·6	41·7	20·3	23·8		723·3	75·4	110·5	79·9	75·2	76·6
" at commencement of compression in L.-P. cylinder . .	$I^c{}_3$	..	..	..	..		270·0	72·4	190·7	24·6	24·6	23·1
" at end of do. do. . . .	L_{c4}	..	..	..	..		299·4	63·1	136·1	20·2	24·3	24·2

TABLE IV.—HEAT from BOILER and CHECK on SAME by REJECTED HEAT.

——	—	L	M	N	O	P	Q	R	S	T	U
Heat passing through engine per stroke—											
T. U. from boiler as dry steam	M H	1253·7	1570·2	1193·6	1359·3	8524·0	1628·0	1774·4	649·1	847·4	849·4
T. U. " " as priming water. . .	$M_p h$	2·8	3·5	2·7	3·1	19·0	11·6	12·6	1·6	2·0	2·0
T. U. " " by condensation in H.-P. jackets	$M_{JH} L$	50·1	..	47·5	47·5	145·0	96·8	70·7	25·4	24·9	27·9
T. U. " " " L.-P. "	$M_{JL} L$	..	..	..	..	140·0	97·8	98·2	37·7	44·7	43·9
Total heat through engine per stroke . .	Q	1306·6	1573·7	1243·8	1409·9	8828·0	1834·2	1955·9	713·8	919·0	923·2
Heat retained in condensed steam . . .	Q_1	62·8	92·2	59·7	69·2	603·5	107·7	111·6	24·9	35·9	35·0
Heat absorbed by injection water . . .	Q_2	..	..	..	..	7480·0	1388·5	1490·1	551·2	706·5	733·5
Indicated work in T. U.	W_i	129·8	130·4	127·8	130·8	604·5	255·8	257·7	100·3	130·4	133·2
Radiation	R	8·8	8·8	7·0	7·0	88·0	88·0	88·0	12·0	12·0	12·0
Error		..	..	..	..	52·0	44·2	58·5	25·4	34·2	9·5
						8828·0	1834·2	1955·9	713·8	919·0	923·2
Percentage of error to Q . . .						−0·6	−2·4	−2·99	−3·5	−3·7	−1·03

TABLE V.—TRANSFERENCE of HEAT between STEAM and CYLINDER WALLS.

Transfer of heat during one stroke . .	L	M	N	O	P	Q	R	S	T	U
T. U. given up to cylinder walls during admission . . } $Q\,a$	288·2	456·1	201·3	145·6	1,115·6	272·5	249·8	152·8	192·2	185·8
T. U. absorbed by steam during expansion in H.-P. cylinder } $Q\,b$	109·7	162·3	85·2	39·5	321·6	220·9	233·1	131·7	128·5	133·1
T. U. given up to H.-P. cylinder walls during compression } $Q\,d$	4·1	15·5	−1·7	−0·6	165·6	42·4	93·5	29·1	23·0	24·0
T. U. absorbed during H.-P. exhaust $Q\,c$	223·9	300·5	154·9	146·0	1,060·6	176·8	166·9	71·1	107·1	100·1
T. U. absorbed during expansion in L.-P. cylinder . . . } $Q\,b_1$	..	..	..	..	−569·1	261·5	324·7	23·4	33·0	61·6
T. U. given up to L.-P. cylinder walls during compression } $Q\,d_1$	..	..	..	..	− 26·1	18·4	87·2	5·8	1·7	0·3
T. U. absorbed during exhaust from L.-P. cylinder . . . } $R\,c$	..	..	..	..	1,699·6	7·5	3·6	83·7	113·0	75·2
T. U. given up by radiation H.-P. cylinder . . . . . } R_H	8·8	8·8	7·0	7·0	44·0	14·0	14·0	4·5	4·5	4·5
T. U. given up by radiation L.-P. cylinder . . . . . } R_L	..	..	..	..	44·0	24·0	24·0	7·5	7·5	7·5

NOTE.—Where heat passes from the walls to the steam it is "absorbed."
" " " steam " walls " "given up."

TABLE VI.—CONSUMPTION of COAL per I.HP. per HOUR.

—	L	M	N	O	P	Q	R	S	T	U
T. U. per I.HP. per minute calculated from the temperature of the air-pump discharge	409·0	485·7	395·0	438·0	581·6	288·3	305·6	293·7	289·3	285·1
Lbs. of coal per I.HP. per hour, supposing feed taken from hot well and the coal to give up 11,000 T. U. per lb.	2·230	2·650	2·150	2·390	3·172	1·572	1·667	1·602	1·578	1·550
	DISPOSAL OF HEAT ($Q - Q_1$).									
As indicated work per cent.	10·4	8·8	10·8	9·8	7·3	14·8	14·0	14·6	14·8	15·0
Rejected heat and error	88·9	90·6	88·6	89·7	91·6	83 0	84·0	83·7	83·8	83·7
Radiation	0·7	0·6	0·6	0·5	1·1	2·2	2·0	1·7	1·4	1·3

TABLE VII.—RESULTS.

——	L	M	N	O	P	Q	R	S	T	U
Absolute boiler pressure in lbs. per square inch	56·7	55·8	59·4	59·3	55·4	67·8	67·2	78·0	76·0	75·0
Speed of piston in feet per minute	223·4	222·9	240·0	240·0	243·6	284·5	284·4	368·0	366·1	357·2
Total number of expansions	4·33	3·84	3·16	1·95	1·75	11·95	10·23	16·5	13·36	13·15
Type of engine	Single cylinder beam				Bull	Woolf beam		Woolf beam		
Height of barometer during trial, in inches	29·89	29·87	29·92	29·73	30·26	30·21	30·14	30·4	30·4	30·06
Percentage of priming water in steam	1	1	1	1	1	3	3	1	1	1
„ steam passed through jackets	4·94	None	4·9	4·4	4·1	13·4	11·0	11·3	9·7	10·2
Indicated HP.	123·4	123·6	119·5	122·4	174·6	212·98	214·5	132·8	171·9	171·2
Total „	143·4	149·2	128·6	135·2	202·2	229·3	251·9	146·2	184·4	184·4
Absolute „	147·1	154·3	131·5	138·1	220·4	247·3	271·1	151·6	190·6	190·2
Percentage of water present in cylinder at cut-off	29·3	37·0	22·0	14·8	16·7	25·0	24·3	31·0	29·7	28·9
„ „ „ „ at end of H.-P. stroke	23·4	27·5	17·7	14·4	14·7	13·5	13·4	13·4	16·3	15·0
„ „ „ „ at end of L.-P. stroke	..	..	..	..	22·8	1·5	2·64	15·6	17·4	12·4
„ of total heat Q lost by R_c	17·1	19·1	12·4	10·4	19·2	0·4	0·18	11·7	12·3	8·1
T. U. per I.HP. per minute	430·0	515·9	416·3	460·7	624·3	306·3	324·2	304·3	301·1	296·3
Lbs. of dry saturated steam per I.HP. per hour	22·06	26·46	21·3	23·6	32·02	15·65	16·58	15·51	15·36	15·12
Maximum theoretical efficiency	0·265	0·251	0·268	0·267	0·233	0·253	0·250	0·303	0·295	0·296
Actual efficiency	0·099	0·083	0·102	0·093	0·068	0·139	0·132	0·140	0·142	0·144
Percentage of theoretical efficiency actually obtained	37·3	33·0	38·0	34·8	29·6	54·9	52·8	46·2	48·1	48·7

WEIGHT of 1 CUBIC FOOT of DRY SATURATED STEAM in lbs.

Absolute Pressure in lbs. per Sq. Inch.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	0·00303	0·00332	0·00360	0·00388	0·00416	0·00444	0·00472	0·00500	0·00527	0·00554
2	0·00581	0·00608	0·00635	0·00662	0·00689	0·00716	0·00743	0·00770	0·00797	0·00824
3	0·00851	0·00878	0·00905	0·00932	0·00958	0·00984	0·01010	0·01036	0·01062	0·01088
4	0·01114	0·01140	0·01166	0·01192	0·01218	0·01244	0·01270	0·01296	0·01322	0·01348
5	0·01374	0·01400	0·01426	0·01452	0·01478	0·01504	0·01530	0·01556	0·01581	0·01606
6	0·01631	0·01657	0·01683	0·01709	0·01735	0·01760	0·01785	0·01810	0·01835	0·01860
7	0·01885	0·01910	0·01935	0·01961	0·01986	0·02011	0·02036	0·02061	0·02086	0·02111
8	0·02136	0·02161	0·02186	0·02211	0·02236	0·02261	0·02286	0·02311	0·02336	0·02361
9	0·02386	0·02411	0·02436	0·02461	0·02486	0·02511	0·02536	0·02561	0·02586	0·02611
10	0·02635	0·02660	0·02684	0·02709	0·02734	0·02759	0·02783	0·02808	0·02832	0·02857
11	0·02882	0·02907	0·02931	9·02956	0·02980	0·03005	0·03029	0·03054	0·03078	0·03103
12	0·03127	0·03152	0·03176	0·03201	0·03225	0·03249	0·03273	0·03297	0·03321	0·03346
13	0·03371	0·03396	0·03420	0·03445	0·03469	0·03493	0·03517	0·03542	0·03566	0·03590
14	0·03614	0·03639	0·03663	0·03687	0·03711	0·03736	0·03760	0·03784	0·03808	0·03832
15	0·03856	0·03881	0·03905	0·03929	0·03953	0·03977	0·04001	0·04025	0·04049	0·04073
16	0·04097	0·04121	0·04145	0·04169	0·04193	0·04217	0·04241	0·04265	0·04289	0·04313
17	0·04337	0·04361	0·04385	0·04409	0·04433	0·04457	0·04481	0·04505	0·04528	0·04552
18	0·04576	0·04600	0·04624	0·04648	0·04672	0·04695	0·04719	0·04743	0·04767	0·04791
19	0·04814	0·04838	0·04862	0·04886	0·04909	0·04933	0·04957	0·04981	0·05005	0·05028

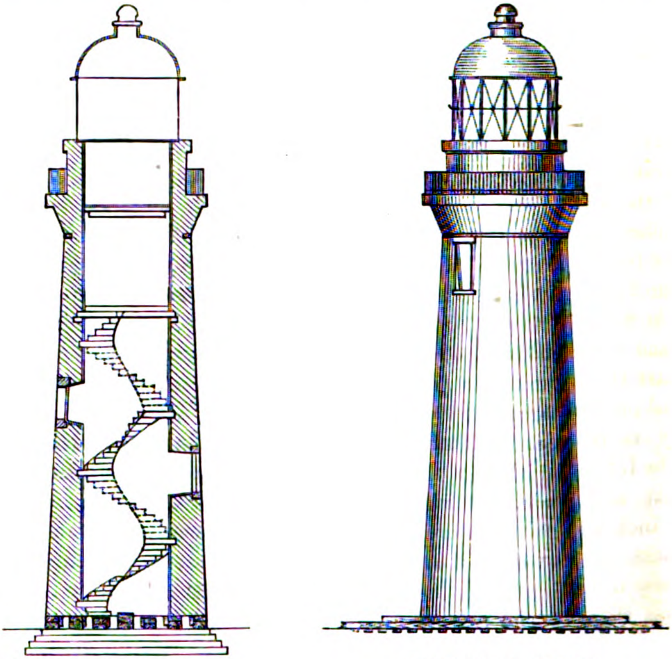
(*Paper No. 2022.*)

"Account of Shifting one of the Lighthouses at Buddonness, near Dundee Harbour."

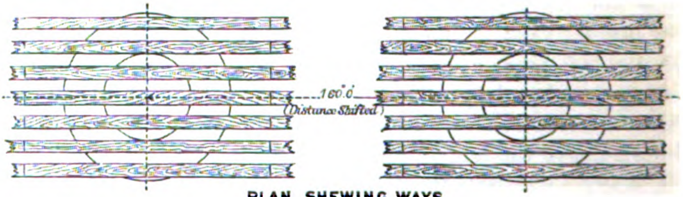
By DAVID CUNNINGHAM, M. Inst. C.E.

THE entrance to the Firth of Tay, which is 10 miles below the Harbour of Dundee, is lighted by two leading lights on the links of Barry, or sands of Buddonness, on the north side of the entrance. These two lights are fixed white dioptric lights, situated in towers respectively 105 and 65 feet high. The entrance to the river had somewhat altered its position from the time (1866) when the towers were erected, the sandbanks having increased outwards towards the sea. It therefore became advisable to shift the line of the leading lights, so that it should run over the centre of the altered entrance. It was suggested to make the light movable; one proposal being to erect a skeleton iron tower to run on wheels. The movement of the sandbanks was found, however, to be slow, and it was therefore thought better to shift the lower or outer tower to suit the altered line of entrance. This tower consists of brick- and stone-work, the diameter at the bottom being 17 feet, and the weight to be moved 440 tons. The work of shifting the tower was finally resolved on by the trustees on the 7th of April, 1884. The tower to be moved was built on a foundation of four courses of large flat stones, each course averaging 9 inches deep; this foundation being sunk in the sand.

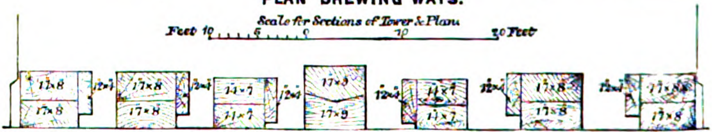
Masons commenced operations in cutting out the masonry and brickwork above the foundation, to receive the timber-ways, on the 5th of May. Materials were taken down to the spot chiefly by river. Seven lines of pitch-pine timber-ways (see cut next page) were intended to be put under the tower. Six of these had flat surfaces, and wooden flanges to keep the upper way from moving laterally on the under ways. The central way was made of a flat V shape. The ground over which the tower had to be moved was fine sand, in which water stood at a depth of 3 feet below the surface. The ways were bedded on cross sleepers 22 feet long, 9 inches by 4½ inches, and set 9 inches apart, so as to admit of their being packed up underneath. Where the ground dipped, a cradle of longitudinal sleepers on under cross-sleepers had to be put beneath the upper cross-sleepers. The depth of the brick and masonry which had to be removed at the base of the tower



VERTICAL SECTION OF TOWER. ELEVATION OF TOWER.


160.0
(Distance Shifted)

PLAN SHEWING WAYS.


Scale for Sections of Tower & Plan
Feet 10 5 0 10 20 Feet
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17×8
12×4
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14×7
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17×8
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14×7
14×7
12×4
17×8
17×8
12×4
17×8
17×8
Scale for Cross Section
Inches 12 6 0 1 2 3 4 5 6 Feet

CROSS SECTION OF WAYS.

REMOVAL OF BUDDONNESS LIGHTHOUSE.

for the reception of the seven sets of ways was 18¾ inches; 8 inches representing the depth of the bottom ways; 8 inches of the top ways, and 2¾ inches for wedges on the upper surface of the top ways. The base of the tower above the ways was bound round by four or five turns of ⅞-inch chain, secured together at the ends by union screw, and made taut by hardwood wedges being driven between the chain and the brickwork of the wall. Internally a strong iron hoop in two halves was inserted at the same level as the chain outside, and eight wooden shores radiating from the centre kept the hoop close upon the brickwork inside. Such arrangements were deemed necessary to prevent risk of fracture of the walls. On the 14th of May the ways were all in position under the tower; six wooden piles had been driven at the end of the bottom ways, and a beam placed across their front, from which purchase could be obtained to force forward the upper ways, which had a similar beam placed across their ends. Six ordinary hand-screw jacks, with two men at each jack, were employed to start the tower on the ways. The tower started without difficulty, and on trial the sliding was continued by three jacks, each actuated by one man, so that in a short time the tower was shifted 10 feet. The lubricant used for the ways was a composition of tallow, black soap, and black lead. The general rate of movement was about 1 inch per minute; the force employed being two hand-screw jacks, each actuated by three men. It was found impossible to keep the ways entirely free from sand, and the amount of friction was thereby unavoidably increased. The four courses of foundations were taken out so soon as the tower had been moved sufficiently far off, and they were rebuilt in the new position 160 feet north-east of the old site. This work, and the shifting of the lighthouse into position on the foundations as altered, occupied fourteen days, and the taking out of the ways, and rebuilding the vacancy at the base of the tower, seven days more. The whole work was completed on the 4th of June, being exactly one month from the commencement of operations. The tower on the new site has been elevated 7 inches above its old level, by sliding it upwards on the ways; the object being that the light should be somewhat clearer of the sandhills in front. The whole operation was executed by the ordinary harbour workmen and foreman, under the superintendence of the Author, the Engineer to the trustees, for the sum of £285 1*s.* 9*d.*; of which, however, £118 8*s.* 2*d.* represents the cost of transmitting men and materials to and from the harbour works, which were about 10 miles from the site of operations; the net cost of the shifting, after such deduction, having been £166 13*s.* 7*d.* The cost of the timber-ways, however, was not reckoned as part of the cost of the work, except in so far as they might have been damaged; but the cost of excavating and rebuilding the new foundations, including brick, some hewn stones, lime and cement, was included. The maximum number of men employed did not exceed twenty, the average being somewhat lower. No accident of any kind occurred during the operations.

Drawings and photographs explanatory of the work accompany the Paper, and from one of these the woodcut has been produced.

(*Paper No. 2026.*)

"The Burnham Sewerage Works."

By Alfred Barton Brady, Assoc. M. Inst. C.E.

(*Abstract.*)

The town of Burnham, in Essex, is situated on the northern bank of the river Crouch, at about 5 miles from its outfall into the North Sea; some portion of it is below high-water of spring tides, from which it is protected by extensive embankments. The population of the town is (1881) 2,024, and it is within the Rural Sanitary District of the Maldon Union. In 1883 a scheme of sewerage and sewage utilization was designed by the Author and received the sanction of the Local Government Board in July of that year. The works were immediately submitted for tender, and let to Mr. J. W. Steward, of Southend, who completed his contract in April, 1884. The sewering is of an ordinary character, consisting of about 2¾ miles of glazed earthernware pipes, varying from 6 to 15 inches in diameter, and accommodating a district of 57 acres, on which are four hundred and thirty-five houses; but ample provision exists for the future extension of the town, anticipated when the railway reaches it. At present the nearest station is Maldon, 13 miles distant.

The 15-inch outfall sewer is 336 yards in length, and has a gradient of 1 in 1,000. From its commencement at the manhole near the "Kangaroo" coastguard ship to the outfall works, it crosses three meadows, and is, for the greater part of its length, in an embankment formed to a depth of 18 inches above the top of the sewer. This bank is 42 inches wide on the surface, with side-slopes of 1 to 1; the top is metalled, to form a foot- and barrow-path, and the sides are turfed. Ample means have been provided for flushing the sewers by admitting water from the river Crouch at high tide. For this purpose a line of 9-inch pipes was laid from the manhole near Birmingham Square to the river, the mouth of the pipe through the river-wall being protected with a tide-flap, and the end in the manhole being fitted with one of Mr. Bailey Denton's flushing penstocks. By opening this penstock and the tide-flap, at a proper state of the tide, the river-water rushes through the 9-inch pipes nearly full bore, and along the 15-inch main sewer half full, with considerable velocity, thereby effectually removing all sediment. For the first fifteen minutes the flushing water is allowed to run into the tanks, in which time all the sewage is flushed out of the pipes; when the water is diverted, by an arrangement of penstocks, into a marsh dyke leading into the tidal stream, and allowed to run as long as the height of the tide will permit.

Two sewage-flushing tanks were constructed on the lines of the sewers, viz., one at the junction of Queen Street with Burnham Road, and the other at the north end of Chapel Street. Each tank is 50 feet long, circular in cross section, of 3 feet internal diameter, and divided into two compartments by a 9-inch brick-wall, having an opening for communication at the invert level, fitted with a 12-inch hand disk-valve. Each flush-tank will hold 2,000 gallons. The object of the division into two compartments is that in dry weather, when it would take too long a time to fill the entire tank, one compartment only may be used; in wet weather the tanks may be used to their full capacity.

There are ten dead-ends in the system of sewers, from each of which the sewers are flushed from a water-cart, constructed to hold 250 gallons; the whole being discharged in a few seconds by means of a large outlet-valve, to which is attached a leather hose, 7 feet long and 8 inches in diameter. This cart is also adapted, and is used, for watering the streets, when not in use for flushing.

The flushing water in the 9-inch branch sewers is intercepted, and made to do duty over and over again, by plugging up the outlet in each successive manhole, until the main is reached, with conical-shaped plugs, leather bound.

The 15-inch outfall sewer is capable of delivering, when running two-thirds full, 889,198 gallons in twenty-four hours, or at the rate of 2,044 gallons per hour, during that time, for the four hundred and thirty-five houses within the drainage area.

Taking the population at 2,324, and assuming 15 gallons per head as the probable quantity of sewage, that would amount to 30,870 gallons only, which would leave 858,328 gallons as the contribution of surface-water, equal to 0·672 inch in depth over the 57 acres within the drainage area; but as there is a considerable area included in the sewerage district which is either pasture or garden-ground, certainly not more than one-fourth of the rainfall could possibly reach the sewers.

There are three storm-water overflows provided in the lower part of the town, for the relief of the outfall-sewer during periods of excessive rainfall.

The outfall works consist of screening- and filter-tanks in duplicate, to allow for the removal of the deposited sludge, and the cleansing or renewal of the filtering materials. The tanks are constructed of gray stock bricks, built in Portland cement mortar, and backed with puddled clay. The walls are coped with bull-nosed blue Staffordshire bricks, on edge, beyond which is a margin of three courses of blue bricks laid flat, making a good footpath nearly 2 feet in width surrounding the tanks. The floors of the tanks consist of common bricks, laid on edge, grouted with cement, upon a foundation of Portland cement concrete 6 inches thick. The sewage is first received into a small intercepting chamber, fitted with two oak sluices, by means of which it is directed into either set of tanks. In flowing through the tanks, the sewage is deprived of the grosser matters by means of two rows of removable wire screens, supported on dwarf walls, and made to slide in grooved piers.

The further deposition of the solids is aided by a weir, over which the sewage flows in a thin sheet to a filter-bed of sand and assorted gravel. Through this it gravitates and passes through a dwarf wall, built with 1¼-inch open vertical joints. The sewage then flows in a thin sheet over a second weir, through a second similar filter-bed, and another open-jointed dwarf wall, finally passing along a channel in a clarified state to the marsh dyke.

The level of the outfall into this dyke is 1·25 foot above ordnance datum, or 10·07 feet below high water of ordinary spring tides. The average level of the marshes is 6·12 feet above ordnance datum, or 5·20 feet below high water of ordinary spring tides.

The top of the river-wall or bank is 15 feet above ordnance datum.

The effluent from the tanks has to pass along the marsh dyke for a distance of 1,100 yards, to the "pile-house" sluice, where it flows at suitable states of the tide, with the land-drainage, into the river Crouch. The outfall works are approached by a small brickwork bridge, constructed over the marsh dyke.

There is a pair of strong, oak-framed and braced gates, hung to oak posts at the entrance to the works.

The whole of the ground surrounding the tanks, within the boundary fence, was levelled and metalled with 6 inches of coarse gravel, level with the coping of the tanks.

The sewage tanks are frequently cleared; one set being cleaned whilst the other is in operation. Each screening tank contains $17\frac{1}{3}$ cubic yards of sewage; and when the cleaning begins, the more liquid portion of the sewage is pumped, and the solid portion scooped into iron-bodied sanitary carts, fitted with covers, taken on to the land of a neighbouring farm, and there disposed of.

The layers of sand and assorted gravel forming the filter-beds are removed once in two months, and after being thoroughly washed are replaced in the tanks, with such additional sand as may be required. The total cost of the works was £2,800, inclusive of the purchase of land, compensation, legal and engineering expenses.

The Paper is accompanied by a map of the sewerage district; two drawings giving details of the pipes and fittings, and copies of the specification and regulations as to house-drains.

(*Paper No. 2030.*)

"The Tekapo Bridge, Mackenzie County, New Zealand."

By Frederic William Marchant, Assoc. M. Inst. C.E.

The traffic of the inland road between the provinces of Canterbury and Otago was formerly carried over the Tekapo river by a ferry-boat worked by the river-current. Frequent floods and heavy N.W. winds during the summer often prevented the use of the ferry for a day or two, while the cost of repairs and of maintenance was also very heavy. For these reasons it was decided to bridge the river.

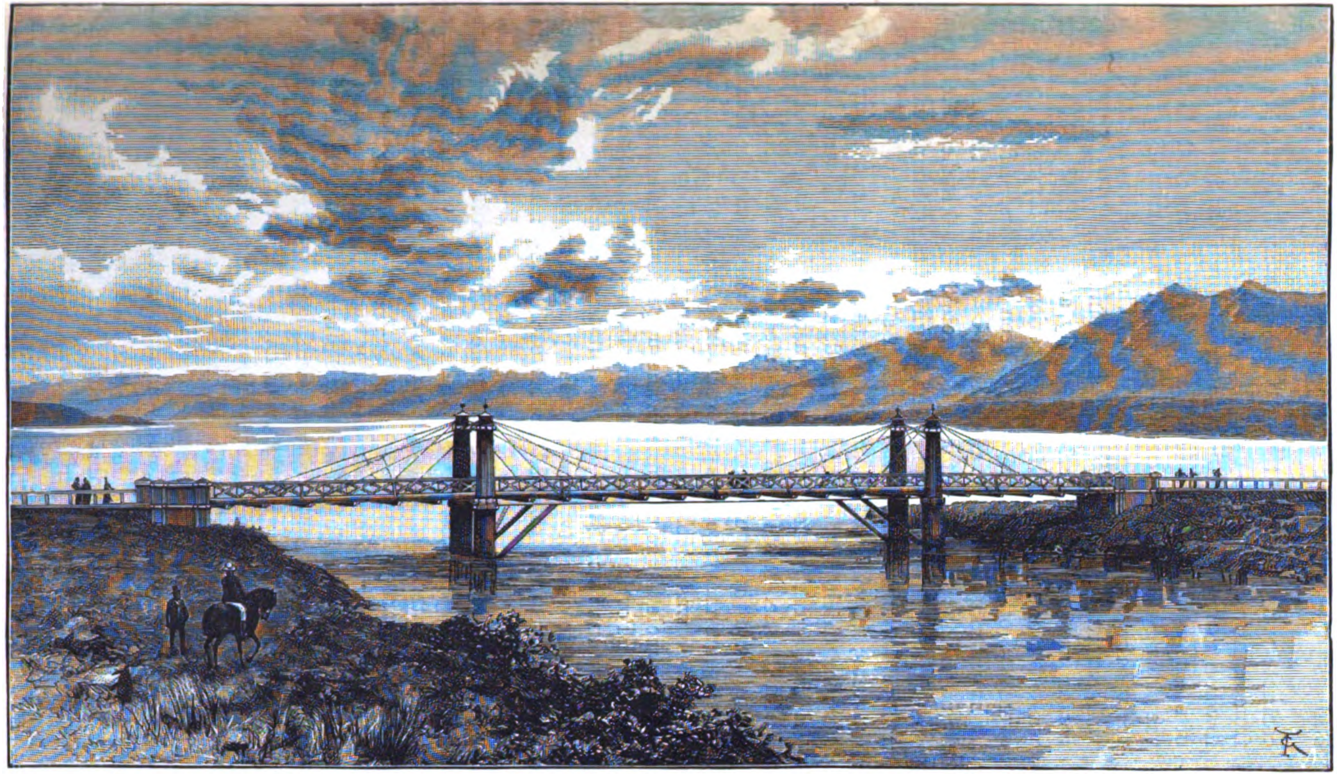
The Author was instructed by the local governing body to prepare a design and estimate of the cost of the work. After a careful examination of the river-channel he selected a site for the work where the river emerges from the Tekapo lake, the altitude being 2,320 feet above sea-level. The lake is a fine sheet of water about 15 miles in length. It is principally fed by the Macaulay and Gooley rivers, having their sources among the large glaciers which abound in the Alpine ravines. In the spring and summer, violent N.W. gales of wind and rain sweep over the mountains, rapidly melting the snow and ice which has accumulated during the winter, causing very heavy floods in the rivers draining them. In the winter nothing but snow falls in the mountains, and then the rivers dwindle down into very insignificant streams. The Tasman river, which drains all the eastern slopes of Mount Cook and the Alpine country adjacent to it, and where is the great Tasman glacier, larger than any in Europe, is 17 miles to the westward of the Tekapo lake.

From the Author's observations of the Tasman river he estimates its lowest winter discharge at but 350 cubic feet per second, and the average autumn and winter flow at 650 cubic feet per second, the drainage area discharging this being about 320 square miles. These figures will give some idea of the volume of water in the forms of ice and of snow stored up in these mountain regions in the winter, to be discharged during the spring and summer.

The Tekapo lake owes its existence to an ancient moraine which dams up the valley in which the lake is situated. The river, in passing through this moraine, is confined to a permanent channel for a distance of about half a mile before it spreads out into a wide rambling shingle-bed from 4,000 to 5,000 feet wide, after the manner of the rivers in the Province of Canterbury generally. The moraine consists of glacial silt with large boulders imbedded in it, some of them several cubic yards in measurement, and strewed all along the river channel. On this account piles could not be driven in the midde of the river, and it was therefore necessary to make one long span and place the piers so that boulders would interfere with their construction as little as possible.

The bridge consists of three spans, the centre of 150 feet and the end ones of 75 feet each. The girder carrying the roadway is of Kauri and ironbark timber, supported on concrete columns by means of twenty-eight 4½-inch iron-wire ropes passing over cast-iron sheaves on the heads of the columns. These columns are 6 feet in diameter at the base, diminishing to 3 feet 6 inches under the cap, the highest being 48 feet from the foundation to the top of the cap. The wire ropes are spliced to adjusting-shackles which encircle ironbark transoms carrying the girders, and are kept from sagging by gas-barrel sprits. The foundations of the columns consist of twenty-four Totara piles on the east side, and of eighteen ironbark piles on the west side, driven from 16 feet to 18 feet in the river-bed.

It was originally intended to lay the river-bed bare, by means of a cofferdam, to get in the column-foundations; but after trial it was found impossible to staunch it on account of the boulders above referred to. It was then decided to drive piles at as regular intervals as the boulders would allow, cut off the heads 9 inches below the lowest winter level of the river, and lay the concrete under water, which at the site of the west column, and while the foundations were being laid, varied from 7 to 10 feet in depth. Accordingly the site of one column was enclosed by a timber caisson 12 feet square, and the river current shut out by means of a tarpaulin stretched around the caisson and extending out over the river-bottom, to which it was kept close by heavy stones. A square tube of timber, 10 inches by 10 inches at the bottom diminishing to 8 inches by 8 inches at the top and surmounted by a hopper, was used for laying the concrete. A board shutting the bottom of the tube was carried by ropes made fast to the top of the tube, which was suspended by pulley-blocks from a gantry, enabling the tube to be raised or lowered and moved all over the area of the caisson. Some



View of the Tekapo Bridge, N.Z.

concrete was filled into the tube above water, and was prevented from falling out by the closing board. The tube was gradually lowered to the river bottom, concrete being filled in and the level of it always kept above water. When the tube reached the bottom the closing board was drawn away, and the column of concrete in the tube then rested on the river-bed. The tube was next filled up with concrete to the hopper top, and being slightly raised from the bottom, the concrete flowed out steadily, and as it flowed the hopper was filled up. No difficulty was experienced in laying the concrete evenly all over the caisson and between the piles. After it had set eight or ten days and the caisson had been removed, the result was found to be quite satisfactory. Concrete 3 feet 6 inches thick rests on the pile-heads to distribute the weight of the columns over them. In the first foundation laid, broken stone was employed for the concrete; it was not, however, so satisfactory for the purpose as shingle, which was afterwards used, the latter flowing from the tube with greater steadiness and squeezing into angles better than broken stone. As a proof of the steadiness with which concrete flowed from the tube when shingle was used, it may be mentioned, that when the tube was at work, in a depth of 1 foot only, no turbidness was visible from cement being washed out.

The whole of the concrete in the upper work is of broken stone, sand, and Portland cement, ranging from 1 of cement to 4 of stone in the columns to 1 to 8 in the abutments and wing walls; sand sufficient in quantity only to flush up the interstices of the stones being used. All exposed concrete work is neatly rendered in cement mortar.

On completion the bridge was tested with a rolling load of about 20 tons weight, the vertical deflection under which was ⅜ inch, while the lateral oscillation was about the same amount. During the four years it has been open for traffic no settlements or cracks have occurred in the concrete, while the girder retains the camber to which it was adjusted at the termination of the work.

The works occupied eleven months in construction, and cost, exclusive of road approaches, £5,100.

Owing to the high wind-pressure common to this locality it was considered advisable to take some extra precautions to stiffen the work against it. The spans are strongly braced by iron rods, the planking laid diagonally, and the ironbark struts under the centre span slightly splayed.

The site being 66 miles inland from the seaport of Timaru, necessitated 28 miles carriage by rail and 38 miles by road for all material and plant used. The difficulty of conducting operations in a swift river, frequently in high flood during the only time work could be carried on, while severe frosts and heavy snows stopped work during the winter, combined to run up the cost to a very large percentage more than it would have been the case at a more favourable site.

The Paper is accompanied by two photographs, from one of which the woodcut has been engraved.

OBITUARY NOTICES.

JOHN HALLEN ABBOTT was born on the 26th of February, 1831, in Nicholas Lane in the City of London, where his father practised as a solicitor. He was educated at Kennington and at Bexley Heath, and early in 1850 was articled to the late Sir Charles Fox, M. Inst. C.E., and after passing through the shops of Messrs. Fox, Henderson & Co. at Birmingham, was for a few months engaged in the preparation of the drawings for the first Exhibition building in Hyde Park in 1851. In 1852 he was sent to Denmark by Sir Charles Fox to assist in the construction of the Zeeland Railway from Roeskilde to Korsoer, remaining there until the completion of the line in 1856. In February 1857 Mr. Abbott was appointed a Third-Class Assistant Engineer in the service of the Great Indian Peninsula Railway, and proceeded at once to Bombay. Although the engagement was only for a period of three years, he was in October 1858 promoted to the grade of Second Class, and in March 1862 was made Resident Engineer. In March 1865 he was appointed District Engineer, having charge of a length of 139 miles of construction, and in 1870 was made Chief Engineer of the north-east Division of the Company's system, being a length of about 750 miles. On two occasions Mr. Abbott officiated as Chief Resident Engineer of the whole railway—once for twelve months for Mr. J. R. Manning, M. Inst. C.E., in 1871, and again for twelve months for Mr. Wilson Bell, M. Inst. C.E., in 1881. He remained in the service of the company until his death in 1884, a period of upwards of twenty-seven years. On his first arrival in India only about 100 miles of the railway were completed, and there was probably not a mile of the 1,350 miles subsequently constructed in which he had not a hand, either in the way of making surveys, superintending construction, or in maintaining after opening. For some months he had been in failing health, and becoming suddenly worse was ordered home in June. It was scarcely expected by his friends in India that he would live to reach England, but being carefully nursed during the voyage by an old friend and colleague, he managed to do so, but died on the 5th of October, a few weeks after arrival, of a combined attack of liver complaint and dropsy. Mr. Abbott possessed unusual personal attractions and genial manners, and of all the engineers engaged from first to last on the Great Indian Peninsula Railway, he was probably the most generally popular, not only among the officers and men in his own department, but also among those in the locomotive and traffic departments. He was always foremost to assist the destitute and needy, his generosity keeping him a comparatively poor man to the day of his death. He took great interest in the establishment of the Great Indian Peninsula Railway Volunteer Corps, and at his death was the Major of the Regiment. His friends in India propose to erect a monument over his grave in Beddington Churchyard.

Mr. Abbott was elected a Member of the Institution on tho 3rd of December, 1867.

JAMES BELL, born at Newtown Forbes, Co. Longford, in 1829, was the eldest son of Mr. James Bell, who practised as an architect and builder in earlier life, and was Co. Surveyor of Longford for forty years. James Bell, jun., was sufficiently competent, at an early age, to hold an appointment as Assistant-Engineer on the Famine Relief works of 1847–8. He afterwards entered the office of Mr. (now Sir Charles) Lanyon (then Co. Surveyor of Antrim, and engaged in extensive practice as an engineer and architect in Belfast and the North of Ireland) as an articled pupil. At that early period of life he displayed unusual ability, especially as a draughtsman, in advance of the recognized standard of thirty years ago, and an original and somewhat daring genius for architectural design, which, if pursued and chastened by more experience, might have resulted in conspicuous success in the sister profession. After holding some appointments under Sir Charles Lanyon, as Resident-Engineer and Clerk of Works at the Belfast Lunatic Asylum Buildings, 1850–4, Mr. Bell passed into the Board of Works Office as Chief Draughtsman, where he took part in the design of many departmental works of importance with which his name was, of course, not identified. At this time also he was engaged with Mr. James Farrell, C.E., Co. Surveyor of Wexford, as joint architect for the Lunatic Asylum at Enniscorthy, and for which the plans were prepared by Mr. Bell. After assisting his father for a year, he in 1862 competed for the post of Co. Surveyor of the North District of the County of Dublin, obtaining the appointment against seven candidates selected from seventy competitors. Thenceforward until his death on the 23rd of October, 1883, at the comparatively early age of fifty-four, Mr. Bell continued to discharge the routine duties of his office. He also designed and constructed several heavy works, such as sea-walls, repairs and additions to harbours, &c., occasionally engaging in architectural competition, exhibiting the powers and vigour of design which his professional contemporaries and intimate friends credited him with. Of taking appearance and genial manner, he inspired the personal regard of many friends, attracted by a character singularly affectionate and humorous.

Mr. Bell was elected a Member of the Institution on the 4th of February, 1879.

WALTER RALEIGH BROWNE, late Fellow of Trin. Coll. Camb., was born in 1842. He was the third son of the late Rev. J. Murray Browne, vicar of Almondsbury, and honorary Canon of Gloucester Cathedral. He was educated at home till he went to Trinity College, Cambridge, in 1861. In 1863, he obtained a College Foundation Scholarship, and graduated, after a University career of much distinction, as 19th Wrangler and (bracketed) 10th Classic in 1865. He obtained the Wrangham and Leigh gold medal and prize, granted only to those Trinity College men, who, besides being in the first class in both triposes, have also been invariably in the first class in the college examinations. Whilst at Cambridge he read Greek Testament largely, being College and Dealtry prizeman for two successive years. He became Fellow of his college in 1867. His love of mechanics decided his profession, and he served his time as an engineer, first with Messrs. Losh, Wilson and Bell of the Walker Engine works on the Tyne; and afterwards with Mr. Howard, resident engineer of the Bristol Dock and Harbour works. Whilst there he took an active part in important works connected with the docks which were then in progress; and the result of his experience and observations was given in a Paper "On the Strength of Lock-Gates," read before the Institution of Civil Engineers in 1871,[1] for which a Telford premium was awarded.

On the completion of his apprenticeship, he entered, as junior managing partner, the Wokley Ironworks, near Kidderminster, but soon retired from the firm and returned to Mr. Howard early in 1872, as confidential adviser and assistant during the temporary ill-health and absence of the latter. During this year, he read before the Institution of Mechanical Engineers a Paper "On the Strength and Properties of Riveted Joints," which has since been recognized as an authority on the subject. In 1874 he became managing Director of the Bridgewater Engineering Company. Always throwing himself heartily into whatever work he had to do, he gave his attention to the construction of railway-wagons, and embodied his conclusions in a Paper read before the Inst. C.E. in 1876, "On Railway Rolling Stock."[1] This Paper was placed first in order of merit amongst those read during the session, and received a Telford medal and premium. Depression in trade caused the Bridgewater works to be closed, and he then became Secretary to the Institution of Mechanical Engineers, a post which he held for six years. He resigned it, however, together with his membership, in January 1884, and started as a consulting engineer, with every prospect of success. He was employed by the Mersey Dock and Harbour Board, in connection with the proposed Manchester Ship Canal, and this necessitated frequent visits to the Continent during the last six months of his life. The subject, dealing as it did with harbour and tidal *versus* upland waters, was one in which he had long been interested, and on which he had contributed a Paper in April 1881 to the Inst. C.E. In that communication on "The Relative Value of Tidal and Upland Waters in Maintaining Estuaries," he gave, amongst other information, the results of some experiments made for him in the River Avon, by Professor H. S. Hele Shaw of Bristol University. A series of articles, dealing thoroughly with the question, was to have appeared in the "Engineer," but a fragment, produced on his voyage to Canada, is all he had put on paper.

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[1] Minutes of Proceedings Inst. C.E., vol. xxxi., p. 317.

In August 1884 he went to Canada, with his wife, in order to attend the meeting of the British Association. The morning after his arrival in Montreal he was so unwell that medical aid was sent for. On Thursday, August 28th, typhoid symptoms became apparent, and he was moved from the house where he had been most hospitably received, to a private ward in the General Hospital, where everything that human care and attention could suggest was done. But by Sunday, inflammation of the lungs had set in, and he died at midnight on Thursday, September 4th, at the early age of 42. The funeral took place in the Mount Royal

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[1] Minutes of Proceedings Inst. C.E., vol. xlvi., p. 81; lxvi. p. 1.

Cemetery on the following Saturday, and was attended by Sir W. Dawson, and other professors of M'Gill University, as well as by some of the leading citizens of Montreal.

During his residence in London, Mr. Browne devoted much attention to the theory of mechanics. He wrote a series of articles in the "Engineer," entitled "The Foundations of Mechanics," which were reprinted, and were followed by a book dealing with the same subject, entitled "the Student's Mechanics." Besides these, he read before the Physical Society, and published in the "Philsophical Magazine," &c.: Papers on "Action at a Distance," "Central Forces and the Conservation of Energy," "The Reality of Force," &c.

He was early attracted to the much disputed point of glacier-motion, not only as an enthusiastic mountaineer and member of the Alpine Club, but also by the friendship of the late Canon Moseley, who advanced the theory of the Dilation of Ice, and which Walter Browne was engaged in defending at the time of his death. It was long before he was able to endeavour to establish Moseley's theory by Papers read before the Royal Society, Physical Society, and the French Academie des Sciences.

Besides the above mentioned writings on physical science, he translated Clausius's "Mechanical Theory of Heat," and Schwackhofer's "Fuel and Water." To the latter work, he acted as editor in order to fit it more to the needs of English steam-users, and prefixed a clear and concise account of the Mechanical Theory of Heat. In the spring of 1884, he read before the Iron and Steel Institute, by special request of the President, a Paper on "Iron Sleepers." His literary ability made him a valuable writer on scientific subjects, and he contributed more or less frequently to the "Engineer," "Nature," "Athenæum," "Church Quarterly Review," "Builder," "Electrician," "Coal and Iron Trades Review," &c., &c.

Mr. Browne was a member of the Geological, Royal Geographical, Physical, Philological, Psychical-Research and Aristotelian Societies, and as a connecting-link between his scientific and his philanthropic work, the Christian Evidence Society. All these societies have lost an active and interested member. He contributed several Papers to the Philological Society, of which he was a Member of Council; amongst others, two on "Scotch and English place-names" (compiled mainly during leisure evenings), and on "the Origin of Technical Terms," chiefly engineering, which disclosed some curious and interesting facts. Besides this, he took an active interest in and contributed to the Society's "New English Dictionary." He was one of the founders of the

Society for Psychical-Research, and the metaphysical questions debated at the Aristotelian Society possessed great interest for him. In connection with these problems, he has left in MS. an "Essay on Evidence"—the result of many years' thought, and which he considered as the work of his life.

The interest felt and work done in philosophy was not a mere matter of "intellectual gymnastics," but was prompted by an earnest desire to know the truth, and to do what he could for the cause of religion. He frequently lectured for the Christian Evidence Society, and in 1876, held, at their request, a public debate, lasting two evenings, with Mr. Bradlaugh, in the Victoria Hall, Leeds; the subject being "Can Miracles be proved possible?" For work such as this, his gift of public speaking and unfailing temper and courtesy, rendered him peculiarly fit. Amongst his published papers connected with this subject may be mentioned a review of the "Autobiography of J. S. Mill," and a brilliant Paper on the "Limits of Authority and Freethought," which attracted much attention at the Derby Church Congress two years ago. In 1880 he published a volume on "The Inspiration of the New Testament," which was favourably noticed by the late Archbishop of Canterbury. He was thus enabled to put before His Grace a point he had much at heart, namely, the necessity for some high-class organization to correct the unbelieving tone adopted by the daily press, and in a great measure by the leading periodicals, and a private conference of leading scientific men was subsequently held at Lambeth Palace to discuss the matter.

In philanthropic work he was active in encouraging emigration, and he held strong views on the paramount importance of maintaining and fostering good relations with the colonies, which he expressed in a Paper on "The Causes and Remedies of Bad Trade," read before the Society of Arts in 1882.

While at Bristol he started the branch of the Discharged Prisoners Aid Society which exists there, and he was a member of the Central Committee in London. He was interested in the vexed question of the education of pauper children. He joined the "Churchmen's Union" when first started by Dr. Wilkinson, now Bishop of Truro, and was an original member of the Church of England Purity Society.

In controversy he hit hard, but never ungenerously. In business he showed to all with whom he came in contact due consideration, patience and perfect courtesy, and he was always ready and pleased to lend a helping hand to any young man at the outset of his career. In society he was a pleasant companion, and a good talker; while those who had the privilege of knowing him intimately and in his home, know with what unfailing chivalry the best qualities of heart and mind were at the disposal of those with whom he had to do.

Mr. Browne was elected an Associate of the Institution on the 7th of April 1868, and was transferred to the class of Members on the 27th of May 1879.

SYDNEY HALL was the second surviving son of Mr. C. H. Hall of Hornings Heath, near Bury St. Edmunds, formerly an officer in the 16th Light Dragoons. He was born at Bury on the 5th April 1813; and was educated partly at the grammar school of that town, and afterwards at Bruce Castle School, Tottenham, under Mr. Hill, father of the late Sir Rowland Hill, the introducer of the penny-postage system. The latter, then Mr. Rowland Hill, was a master in this school, and had commenced to elaborate his famous system. In making the numerous calculations involved he selected Sydney Hall as one of the smartest boys in the school to assist, often keeping him up till far into the night on this work. At Tottenham, Sydney Hall formed a friendship with a schoolfellow, Joseph Cubitt, son of the late Sir William Cubitt, Past-President Inst. C.E. This had much to do with deciding his future line in life. His father had wished him to take Orders in the Church, but to this he would not agree, and at the age of 18, and by the advice of Sir William (then Mr.) Cubitt, Sydney Hall, in September 1831, entered the office of Mr. George Edwards, M. Inst. C.E., of Lowestoft, as a pupil. He remained with Mr. Edwards two years, during which he was principally employed in making observations of the experimental works being carried out for maintaining the entrance of the harbour, and in chronicling their effects. About September 1833 he became a pupil in Sir William Cubitt's office. After the usual training he entered the Horseley Iron Works, near Birmingham. Here he remained for two years, submitting to a regular mechanical education in the various departments, and acquiring a practical knowledge, which he often stated was of the greatest value to him in his subsequent career. Before leaving Horseley he had been promoted to a position of responsibility in the works, so proficient had he made himself in his knowledge of the operations there carried on. He was next employed for some time under contractors upon railway works. Subsequently he went into practice on his own account, and in 1838 joined Mr. J. C. Sherrard, M. Inst. C.E. (who had also been in Sir William Cubitt's office), in partnership as civil engineers and surveyors. The partners enjoyed great success, chiefly in parliamentary surveys for projected railways. Of the latter Sir William Cubitt put a considerable amount into their hands, besides recommending Mr. Sydney Hall for the construction of the Chard and Bridgwater Canal in 1841–3. This was entirely carried out by him, the works including inclined planes and lifts instead of locks for the transference of barges from one reach to another. Railway surveying work kept the firm fully employed up to 1847, when the reaction set in after the Railway Mania, which was at its height in the years 1844–5. The depression that followed in railway engineering was so great that thinking there was little prospect of matters mending, or that there would be much more for civil engineers to do in England for years to come, the firm in March 1848 dissolved partnership.

Mr. Sydney Hall at the time thought of emigrating to Australia, being convinced there was much to be done by the civil engineer in that new country. While, however, arranging for his departure he was requested to visit Swansea to inspect some important works then in the course of erection, by a company formed to manufacture compressed fuel on the patent of a Hanoverian named Warlich. He had previously been induced to take shares in this company (The Patent Fuel Company) and his visit resulted in his being appointed resident director of the company at Swansea. From this time he lived at Swansea and devoted his entire energies to the interests of this company, until in 1871 when he took up his residence in London. During 1871–3 he erected large new works for the same company at Sunderland, capable of turning out 200 tons of fuel per diem. These works, however, soon after changed hands, but under the name of the Wear Fuel-works they are still in full working order.

In 1875 his health failing he had to give up all active work, and passed the rest of his life in London in much suffering and helplessness. He died on the 30th August 1884, in the 72nd year of his age; his mind and intellect being clear to the last in spite of his great bodily trials. He was buried in Kensal Green Cemetery.

Both in the original works at Swansea, and in those at Sunderland, he designed and erected a good deal of machinery of the most ingenious description for effecting the various operations of the manufacture of compressed fuel, much of it forming the subject of numerous patents.

At the Swansea works Mr. Hall accidently made the discovery of aniline dyes. This was quite independently of Mr. W. H. Perkin, who did the same thing and took out a patent for it about the year 1858. The substance yielding the dye Mr. Hall found in one of the large retorts or ovens used for baking the fuel after compression. The fuel, it may be stated, was that made with raw coal tar, not with coal tar pitch. The substance was found only once, and more of it, though sought for, could not thus be obtained. He then set about endeavouring to artificially reproduce it, but at that time failed in discovering any chemical process for doing so, and while engaged in the experiments Mr. Perkin quite independently elaborated and patented a successful process. Mr. Hall carried on experiments for the next few years up to 1863, endeavouring to avoid Perkin's process and strike out a new colour for himself if possible, but in this he failed. He used, however, to aver that he had satisfied himself that his discovery was actually prior to that of Mr. Perkin. At all events this is another instance of a great invention being made almost at the same time by two independent workers.

Mr. Sydney Hall was a man of considerable ability as an engineer, and many of his friends regretted he should have given up the profession and settled down to manufacturing pursuits. In particular, Sir William Cubitt in subsequent years, strongly urged him to resume practice in London, promising to assist him, but this course Mr. Hall did not see his way to adopt. His intimate friends knew him as one not only full of information on an immense variety of subjects, but as equally able of imparting it to others in conversation.

In January 1868 he was appointed a Justice of the Peace for the borough of Swansea. For many years he was a Mercantile Assessor for the Swansea County Court, and one of the Harbour Trustees. In the latter capacity he was re-elected again and again, and did much good service in the post. For some years also he served on the Town Council.

He was elected a Member of the Institution on the 4th April 1843.

CHARLES WOODLEY WHITAKER, second son of Thomas Whitaker, for many years County Surveyor of Devonshire (who is still living at the advanced age of eighty-four years), was born at Exeter on the 17th of April, 1837.

He was educated at Exeter Grammar School, where he was a contemporary of the afterwards eminent Professor Clifford, and others who have done credit to that ancient foundation, and served their country in various departments of professional life. Subsequently he was articled to his father, under whom considerable experience was gained of bridge- and road-works. After being employed by Mr. Brunlees, Past-President Inst. C.E., for about two years, Mr. Whitaker entered the service of the Metropolitan Board of Works, and for eight years was actively engaged under Sir Joseph Bazalgette, C.B., Past-President Inst. C.E., in superintending the Southern High-Level Sewer, the Effra branch, the Southern Low-Level Sewer, and the Albert Embankment at Lambeth. In these important works he had a varied experience, and showed much engineering aptitude in getting over the difficulties which so often crop up unexpectedly in carrying out undertakings of this nature.

Subsequently Mr. Whitaker was engaged in practice as a civil engineer on his own account; and during this period, extending over fourteen years, he designed and superintended the construction of engine-houses, tramways, jetties, &c., on the Thames near Erith. Two bridges over the River Wye, near Ross, in Herefordshire, one being a wrought-iron girder road-bridge, of three spans of 80 feet each, and the other a suspension-bridge with a centre span of 140 feet. The drainage and sewage disposal of the towns of Uppingham and Oakham in Rutlandshire, of Budleigh Salterton in Devonshire, and of Chard in Somersetshire. The Sea-wall and Promenade, with groynes and other defences, at Clacton-on-Sea, were planned and carried out by Mr. Whitaker, and he obtained the first premium of 6,000 roubles for the best design for a bridge over the Neva, at St. Petersburgh, in a competition open to all Europe. This bridge was subsequently constructed by Russian engineers. In 1881 he was appointed County Surveyor of Bridges for West Sussex.

During the last few years of his life, Mr. Whitaker was much occupied with quantity-surveying of numerous engineering works, the cost of which amounted in the aggregate to over £750,000. His death took place at Croydon, on the 31st of July, 1884, after a short but very painful illness, endured with Christian fortitude. In private life Mr. Whitaker's invariable good-temper and kindliness of manner endeared him to a large circle of friends, who deplore his loss.

He was elected an Associate of the Institution on the 3rd of March, 1874, and five years later was transferred to full Member.

HENRY BATSON JOYNER, eldest son of the late Mr. Henry St. John Joyner, of Northwick, Harrow, was born July 9th, 1839. From 1856 to 1860 he served a pupilage under the late Mr. Charles Nixon, M. Inst. C.E. In 1860 and 1861 he was an Assistant Engineer on the Parsonstown and Portumna Railway under Messrs. Nixon and Dennis. From 1862 to 1868 he was engaged on the construction of the Cwm-Orthin Railway and on works for the supply of Tunbridge Wells with water, as Resident Engineer, also under Messrs. Nixon and Dennis. On the completion of the latter, he was retained by the Commissioners of that town as their Resident Engineer till 1870, in which year he left England to take up an appointment under the Imperial Government of Japan, in whose service he remained about seven years—being employed first in the Public Works Department, in the construction of the earliest railway in that empire. On the completion of the first section, namely from Yokohama to Yedo, he was transferred to the Home Department, where his professional ability had a wider field. Among his chief labours were the trigonometrical survey of Japan, and also the survey of the capital, and other works of public utility; and here it may be mentioned specially, that it was he who organized and developed in Japan the Imperial Department of Meteorology (himself training and instructing the native students in a thorough knowledge of that science); and laid the solid basis on which the present system has been built up. For this he held testimonials of high praise and thanks from the government. His great interest in the subject of Meteorology, and the benefit that he felt would accrue to Japan from the development of that science, caused him to write, while still in the Imperial Government service, a non-official pamphlet, entitled, "The Progress and ultimate results of Meteorology, specially considered in reference to Japan."[1]

Mr. Joyner left Japan in 1877, and after a short stay in England, proceeded at the latter end of 1878 to South America, as Engineer-in-Chief for the planning and construction of the extensive water-supply and sewerage system of the city of São Paulo, Brazil. The sewerage scheme for the above named city, with its many ramifications and domestic services, is now in full operation, with great benefit to the city. The water-supply is on the gravitation system; the water being conveyed to the city, a distance of 10 miles, through iron pipes from the springs in the hills of the Cantareira Forest, where are two large reservoirs for accumulation, with their accompanying erections, built in solid masonry, hewn and quarried from the surrounding rocks. In the city are two fine service-reservoirs, built in solid brickwork, lined with asphalte. On the completion of these works in May 1884, Mr. Joyner returned to England, hoping to recruit his somewhat impaired health; but having taken a severe cold, inflammation of the lungs set in, and he died on the 23rd of November, to the deep grief of all who knew his genial disposition, and respected his straightforward and manly character.

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[1] A copy is in the Library of the Inst. C.E.

He was elected an Associate Member on the 6th of May, 1879, and was transferred to Member on the 29th of November, 1881. He was also a fellow of the Royal Geographical and the Royal Meteorological Societies.

WILLIAM DE WINTON PEEL, second son of the late Major Peel of Aylesmore, Gloucestershire, was born at Llanstephan, Radnorshire, on the 22nd of October, 1850, and was educated at Cheltenham College. In December, 1869, he became a pupil of Mr. George W. Keeling, M. Inst. C.E., of Lydney, and assisted in the construction of the Severn and Wye Railway.

When the Duke of Argyll founded the Royal Indian Engineering College at Cooper's Hill in July, 1871, Mr. Peel became one of the first batch of candidates, and passed fourteenth. While at Cooper's Hill he was exceedingly popular, and was both in the eleven and football teams, besides being an oarsman, and one of the four which rowed at Henley in 1872. Having previous to his entrance to the College been a pupil to a practical engineer, Mr. Peel formed part of the first five pupils despatched to India. Arriving in November, 1873, he was sent as an Assistant Engineer (second grade) to the Saidpur Railway, in North Bengal, was raised to first grade in March, 1878, became Secretary to Colonel Lindsay, R.E., and during the Afghan war was sent to Sind as an Assistant Engineer on the Sibi and Quetta Railway. While surveying for this railway, he tumbled down a cliff some 60 feet high, and was invalided home in March 1880. He returned to India in the following October; in May 1881 was made Executive Engineer, Fourth grade, and in 1883 got another step. He was Under Secretary to the Bengal Government P.W.D. Railway Branch at his death, which happened on May 4th, 1884, of typhoid fever, after three weeks' illness at Darjeeling.

Mr. Peel was exceedingly popular in the service, and was said to be one of the most rising Cheltonians in India. Although of a retiring disposition in private life, he was a thorough sportsman, riding well to hounds, was much addicted to pigsticking, possessed a few steeplechase horses, which carried him to victory on more than one occasion, and had many trophies to show of his prowess with the rifle among the bear, the tiger, and other wild animals of the Himalayan forests.

He was elected an Associate Member of the Institution on the 4th of February, 1879.

MERVYN JAMES BUTLER PRATT, son of Mr. James Butler Pratt, late County-Surveyor of Leitrim, was born on the 5th of December, 1857. At the age of fifteen he entered Trinity College, Dublin, and graduated M.A. in 1877, with First Gold Medal, Moderatorship, and Professor Leslie's prize in experimental science. He was for two years assistant to Professor Leslie in the laboratory, and on the death of that gifted man, Mr. Pratt became assistant to his father on the County Relief Works in Leitrim. In May, 1881, he became assistant to Mr. J. R. Manning, M. Inst. C.E., the chief engineer of the Shannon Improvement Works. He built the weirs and sluices at Jamestown, and was subsequently engaged on similar works at Killaloe, Banagher, &c.; he was also engineer to several drainage works in Leitrim and Longford. In 1883 he was appointed by the directors of the Midland Great Western Railway of Ireland to carry out the Killeshandra branch of that line, and was actively employed on the work at the period of his untimely death, which occurred on the 16th of March, 1884, from the effects of a surgical operation.

Mr. Pratt was elected an Associate Member on the 6th of February, 1883, having previously been a Student of the Institution.

CHARLES HARCOURT WHITE was the only son of Lieutenant Abraham Harcourt White, R.N., who died at the age of thirty from the effects of a wound received in action. He was born at Ilfracombe, and on the completion of his education was articled to Mr. George Bush, M. Inst. C.E., at that time Engineer to the Taff Vale Railway. Mr. Bush died in 1842, and Harcourt White was transferred to his successor, Mr. William Gravatt, M. Inst. C.E., with whom he remained until 1846, when he went to the Dublin Board of Works as engineer in charge of the Baronies Barugh and Tirhugh, Co. Donegal, remaining in Ireland about eighteen months. He then took a temporary appointment under Mr. William Haywood, M. Inst. C.E., to make an underground survey of the City of London, in which difficult and tedious work he acquitted himself greatly to his chief's satisfaction. In 1852 Mr. White went to Portugal, and was engaged on the Central Peninsula railway in that country; at first in getting up the surveys, and afterwards with Messrs. Waring and Shaw, the contractors. Mr. White remained in Portugal many years, accepting, on the completion of his engagement with Messrs. Waring, the post of Engineer to the Portuguese Government on the same line. In 1860 he was engaged, under Mr. Valentine, M. Inst. C.E., in getting up the surveys of the South-Eastern Railway of Portugal, and then became engineer and agent to Mr. Edward Price, Assoc. Inst. C.E., the contractor for that line. In 1863 he went to Turkey for Mr. McCandlish, but in the following year returned to Portugal for Messrs. Waring, though on this occasion but for a short time, as his services were afterwards required on the survey and construction of the railway in Honduras. Mr. White's last engagement for Messrs. Waring was on railway surveys in Transylvania. During his long association of nearly twenty years with this firm, he gained the highest esteem of his employers, his loyalty and unswerving integrity engendering a respect which became mutual.

In the last ten or twelve years of his life, Mr. White did little in respect of professional employment; not from distaste of work, but from the fact that his long residence abroad had prevented his undoubted skill and talent from being known, where it was most likely to be appreciated, so that younger and more pushing men got the preference. His modest and retiring nature moreover rendered him averse from the aggressive self-assertion that seems necessary nowadays for the successful professional man. But no failures of worldly fortune could rob him of the possession of high character and stainless honour. The scanty materials from which this notice has been compiled, consisting mainly of testimonials from his various chiefs, seem to vie with one another in their expression of the personal esteem and good-will of the writers, in such a way as to make it manifest that Charles Harcourt White was a worthy scion of a good stock.

He was elected an Associate Member on the 5th of April, 1864, and died suddenly, of heart-disease, on the 27th of September, 1884.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Periodical Movements of the Ground as indicated by Spirit-levels.

By P. PLANTAMOUR.

(Archives des Sciences Physiques et Naturelles, Geneva, 1884, p. 388.)

The sixth year (1st October, 1883, to 30th September, 1884) of these investigations [1] presents features almost identical with those of the preceding one: the curve, traced by the east end of the level oriented east-west, shows a gradual fall of 15 seconds to the end of December 1883; it then fluctuates up and down till the middle of May, having reached its greatest depression, viz., 21·59 seconds, on 24th, 27th, and 29th of April. Its subsequent maximum summer rise—reached on 21st–22nd September—was only 19·39 seconds. It is worthy of remark, that in four years out of six, the east end has shown not only a smaller subsequent recovery in summer than its fall during the preceding winter, but also an annual diminution in the amount of such recovery, and this agrees with observations made over a period of twenty-three years by Professor Hirsch, at Neufchâtel, where the ground movements indicate three septennial periods, during which the *west* end (not the *east* as at Sécheron) has alternately fallen and risen; but eventually has fallen more than it has risen. The mean annual depression at Neufchâtel for these twenty-three years has been 1·59 second, while at Sécheron that of the east end has been 13·44 seconds; if, however, the exceptional cold winter of 1879–80 be omitted, it really amounts to 1·27 second, which is a very fair agreement. Future observations will show if this analogy is maintained, and especially if the septennial periods will also occur at Sécheron.

The oscillations of the ground from east to west in 1884 confirm the remark made last year, that it is the continuity of a certain mean temperature rather than the absolute dates of the maximum and minimum temperatures which influences the epochs of the extreme ground-movements.

The oscillations shown by the level oriented south-north have been as usual less pronounced, their amplitude being 7·26 seconds as against 6·56 seconds last year; and while the south end regularly falls every winter, but gains on this fall little by little each summer, the anomaly—before observed—of its not following the variations of the air-temperature, is still repeated.

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[1] Minutes of Proceedings Inst. C.E., vol. liv., p. 286; vol. lx., p. 342; vol. lxiv., p. 343; vol. lxviii., p. 321; vol. lxii., p. 324; vol. lxxv., p. 326.

E. H. C.

The Permissible Strain upon Brickwork. By Dr. Böhme.

(Mittheilungen aus der Prüfungsstation für Baumaterialien, 1884, p. 80.)

The experiments given in detail in this Paper were made to ascertain the crushing strength of brickwork composed of different kinds of brick with various mortars. The mortars used were made with either lime or Portland cement, in each case mixed with sand. The bricks were those chiefly in use in Berlin. The composition of the mortar was found to have great influence upon the strength. Brickwork set in a mortar composed of 1 part lime and 2 parts sand possessed only 44 per cent. of the strength of the bricks alone, while a mortar composed of 1 part Portland cement and 3 parts sand raised the percentage to 63. A great number of tests were made, full particulars of each being given. The results obtained are summarised in the following Table, in which the safety limit is taken as one-tenth of the absolute crushing strength.

Description of Brick.	Average Crushing Strength of Brick alone.	Permissible Strain upon Brickwork with Mortar composed of—			
		1 Lime. 2 Sand. 4·4 per cent.	7 Lime. 1 Cement. 16 Sand. 4·8 per cent.	1 Cement. 6 Sand. 5·5 per cent.	1 Cement. 3 Sand. 6·3 per cent.
	Lbs. per Square Inch.	Lbs. per Square Inch.			
Ordinary stocks . .	2,930	129	139	161	185
Selected do. . .	3,669	162	176	202	232
Clinkers	5,390	237	259	296	341
Porous bricks . . .	2,617	115	125	144	165
Porous perforated do. .	1,195	53	57	65	75
Perforated do. . .	2,759	121	132	152	171

The figures arrived at by the Author are in each case higher than those upon which the building regulations of Berlin are based.

W. F. R.

On the Adulteration of Portland Cement.

Report to the German Cement-makers' Union.

By Drs. R. and W. FRESENIUS,[1] Wiesbaden.

Portland cement is now adulterated with substances of chemical composition almost identical with the cement itself, differing, however, in physical properties. The difficulties of detection have therefore greatly increased, as even a quantitative analysis does not always enable the analyst to judge with certainty whether a sample has been adulterated or not.

After many experiments, the following method has been devised. It is based on a comparison of some of the properties and behaviour under certain conditions of genuine cement, and of substances used for its adulteration, such as finely ground slag and hydraulic lime. For instance—

a. Specific gravity.
b. Loss by ignition.
c. Behaviour to water; that is, the alkalinity of the aqueous solution.
d. Behaviour to diluted acid.
e. Behaviour to chameleon solution.
f. Behaviour to gaseous carbonic acid.

The specific gravity is determined in the apparatus sketched in page 3, and is based on an accurate determination of what space a given weight of the cement occupies.

In making a determination, the apparatus is first filled to the zero point with turpentine; 100 grams of the cement is then introduced, with the aid of a funnel, into the apparatus through the graduated tube. The cement at once falls to the bottom, and the liquid rises in the tube.

The number of cubic centimetres read off on the tube represents the volume occupied by the 100 grams of cement. By dividing the volume in cubic centimetres into the weight, the specific gravity is obtained.

Precautions necessary in Manipulating.—Keep the lower portion of the apparatus in water at air temperature, and control by thermometer, as constancy of temperature is very important.

Give the apparatus a few gentle taps, in order to facilitate the escape of air-bubbles.

Close the tube with a cork until complete subsidence has taken place, in order to prevent evaporation of the liquid. The results of two experiments ought not to differ more than one unit in the second place of decimals.

The sample of cement in the above, and *for the following experiments*, should be so finely pulverized as all to pass through a sieve with 5,000 meshes to the square centimetre, = 32,257 meshes per square inch, or about 180 per lineal inch.

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[1] The original and a translation *in extenso* are in the Library of the Inst. C.E.

b. Loss by ignition is determined by heating 2 grams over an ordinary Bunsen lamp with chimney until the weight remains constant.

c. Behaviour to water is determined by agitating 1 gram of finely-powdered cement with 100 cubic centimetres distilled water at ordinary temperature, for ten minutes after filtration ; 50 cubic centimetres are titrated with 1·10 nitric acid.

d. Behaviour to diluted acid is determined by agitating 1 gram of substance, finely pulverized, for ten minutes with a mixture of 30 cubic centimetres normal acid, and 70 cubic centimetres water. After filtration through a dry filter, 50 cubic centimetres are titrated back with normal soda solution, and from this the amount of normal acid neutralized by 1 gram substance, is calculated.

e. Behaviour to Chameleon solution.—1 gram finely-pulverized substance, treated with 150 cubic centimetres of a mixture containing 1 part of $H_2\ SO_4$ (specific gravity 1·12), and 2 parts of water. Chameleon solution is dropped into the liquid until it remains red for one minute.

f. Behaviour to carbonic anhydride.—The experiment must be carried out as follows: 3 grams of the finely-pulverized substance is placed in a glass tube at ordinary temperature, and exposed to a stream of carbonic acid gas which has previously passed through sulphuric acid. At further end of glass tube a chloride of calcium tube is fixed, in order to absorb any moisture that might be driven out by the carbonic acid.

At page 8 the results of several experiments are given.

Description.	Specific Gravity.	Loss by Ignition.	Alkalinity of Aqueous Solution $\frac{1}{10}$ N. A. corresponding to 0·5 gram Cement.	1 gram requires Normal Acid.	I gram reduced Milligram.	3 grams absorb Milligram CO^2.
	a	*b* Per cent.	*c*	*d*	*e*	*f*
Portland cement, &c.	3·155	1·58	6·25	20·71	0·79	1·4

One may expect that a genuine Portland cement should possess a—

a. Specific gravity of at least 3·125 ; certainly not less than 3·1.

b. Loss by ignition between 0·34 and 2·59 per cent.

c. An alkalinity of the aqueous solution of 0·5 gram ; substance should correspond to 4 to 6·25 cubic centimetres 1·10 normal acid.

d. The consumption of between 18·8 cubic centimetres and 21·67 cubic centimetres of normal acid, after treatment with 1 gram of cement.

e. The consumption of between 0·79 and 2·80 milligrams Chameleon solution by 1 gram cement.

f. An. absorption of from 0—1·8 milligram C. 0·2 by 3 grams cement. Cements giving results which do not come within the limits given must be looked upon either with suspicion, or as beyond doubt adulterated, according to the results.

TABLE of RESULTS of EXPERIMENTS on ADULTERATED CEMENT.

Description and Composition of the mixture.	Specific Gravity.	Loss by Ignition.	Alkalinity of Aqueous Solution $\frac{1}{10}$ N. A. corresponding to 0·5 gram Cement.	1 gram requires Cubic centimetre Normal Acid.	1 gram reduces Milligrams.	3 grams absorb Milligram CO^2.
	a	*b* Per cent.	*c*	*d*	*e*	*f*
1. One part hydraulic lime, nine parts Portland cement	3·067	1·90	6·50	20·50	not determined	4·6
2. One part hydraulic lime, nine parts Portland cement	3·053	2·52	8·20	20·04		3·6
3. One part of slag neat, nine parts of Portland cement	3·114	2·04	3·8	19·53	6·11	1·6
4. One part of pulverized slag, nine parts of Portland cement . . .	3·115	1·59	4·0	20·6	8·31	0·7
X	3·021	3·72	6·14	19·00	2·10	8·7
Y	3·048	0·55	4·55	17·20	36·40	1·2

The results under the headings *a*, *c*, *d*, and *e* apply to adulteration with slag.

Those under the headings *a*, *b*, *c* and *f* are of use in the detection of adulteration with hydraulic lime.

Analysis of Table on page 10.

No. 1 shows too low specific gravity. Loss by ignition is not normal. Alkalinity of aqueous solution too high, and too great an absorption of C O 2.

No. 2 shows too low specific gravity. A very high loss by ignition. A high alkalinity of the aqueous solution, and too great an absorption of C O 2.

In both cases sufficient proof of adulteration by hydraulic lime.

Nos. 3 and 4. An admixture of slag meal can be recognized by the large amount of Chameleon solution used. In No. 3 the alkalinity of the aqueous solution is below the limit, while in No. 4 it is just reached. The specific gravity of both is below that of genuine Portland cement, viz., 3·125. The consumption of acid gives no information.

C. V. H.

The Cement-Works of the Utica Company at La Salle, Illinois.

By H. C. Freeman.

(Transactions of the American Institute of Mining Engineers, vol. xiii., May, 1884.)

The beds from which this cement is made were discovered about 1838 in excavating for a canal. Hydraulic limestone having been found, a kiln for calcining it and a mill for grinding were erected, and the material was used in the construction of the locks of the canal.

The bed of stone varies from 4 feet to 6 feet 9 inches in thickness, and lies nearly level. The Author subsequently found other beds in the neighbourhood, and in 1869 took charge of the working of them for a company. The beds worked have a total thickness of 16 feet; the rock is obtained wholly by mining, the system of working being similar to that adopted in coal mining. The rooms are worked 45 feet wide, with 15 feet walls between; the main tunnel having side-walls 25 feet thick. The system of drilling is described. The men were paid piecework, and though at first engineers skilled in the management of drills were employed, they were gradually replaced by common labourers. Under the skilled hands it was rare that more than 100 feet were holed in the day of ten hours, but with the new men this was increased to 160 feet and upwards, sometimes reaching 200 feet in the day. All drill-sharpening was at the driller's cost; in order to ensure carefulness, all breakages were charged to the driller, and to prevent waste all the oil was charged for. Moreover, the drillers paid half the cost of the power used to compress the air for the drills, and by this means time-breaking was avoided. The blasting was done by a set of men who did nothing else. Common labourers broke up the stone and removed it in cars to the nearest main entry. Black powder was employed for blasting, after nitro-glycerine and dualin had been tried without success. The "Burleigh" drill was used, and, in the early days, the "tunnel carriage," sent out with the drill by the manufacturers, was employed. This carriage being found to be unsuitable, the Author contrived an improved form of carriage, an illustration of which is given. The improved carriage, with its drill, weighed 1 ton, and was easily handled by the two men who did the drilling, as against nine men under the old system. The description of the rail and track follows. The plant consisted, besides the drills, of a 60-HP. boiler, two Burleigh air-compressors, four kilns, a mill-building and warehouses. The two larger kilns, of 1,000 barrels capacity each, were oval on plan, and the two smaller ones, of 500 barrels capacity, were circular. The larger kilns had eight furnaces, four on each side, and the smaller kilns four furnaces. The kilns were draw-kilns, or perpetual kilns, 45½ feet in height, and having a railway running above them, for loading in the cement-stone in 2-ton charges from the mine. The space below the draw-gates is sufficiently large to cool the calcined rock to a proper degree for handling in wooden cars. The kilns are drawn every two hours, and filled with fresh rock once in twenty-four hours. The calcined stone, after being crushed, passes by an elevator to the top of the mill-house. The mills are self-feeding by spouts from above. Instead of running horizontally, they are set edgeways on horizontal spindles. The stones are 30 inches in diameter, and each consists of a single block of the best French burr; the runner has a speed of five hundred revolutions per minute. Each mill, when in good trim, will grind fifteen barrels per hour of the standard fineness. The wear of the stones is so great that they require to be dressed after the grinding of each one thousand barrels, and should preferably be dressed after grinding five hundred barrels. The power for the mill is furnished by an engine of 210 HP. with two tubular boilers. Rope gear is used to avoid extra engines for hauling. The wire rope, under severe and intermittent strain, runs at the rate of about 2,400 feet per minute. The ropes are ⅜ inch in diameter, of iron wire with hemp centre; the pulleys are 5 feet in diameter, fitted with rubber filling. Steel wires were first employed, but found not to wear so well as those of iron. Particulars with respect to water-supply from an artesian well follow, and also as to the use of water under a 90-feet head to serve the drills. The following analyses are given of the rock and of the cement:—

I. ANALYSIS OF ROCK BY PROFESSOR BLANEY OF CHICAGO.

Carbonate of lime	42·25
„ magnesia	31·98
Clay and insoluble silica	21·06
Iron and alumina	1·12
Silica	0·06
Water	1·07
Total	97·54

II. ANALYSIS OF CEMENT BY G. BODE.

Lime	33·67
Magnesia	20·98
Alumina	9·92
Silicic acid	35·43
Total	100·00

G. R. R.

The Principle of Least Work of Deformation of Internal Forces of Elastic Systems. By W. FRÄNKEL.

(Zeitschrift des Vereines deutscher Ingenieure, No. 27, 1884.)

The Author's aim in this Paper is to show the principle of the least work of deformation is of universal application so long as the deformations are small. This has been disputed by Castigliano and also by Professor Krohn, at page 320 of the "Zeitschrift des Vereines deutscher Ingenieure," 1884.

Considering first the influence of temperature on a statically indeterminate framework. If the temperature of a supernumerary bar A B of length l falls t°, its length would be shortened BB_1 $(= \lambda)$ if it were free, but being fixed a tension T arises in it, lengthening the shortened bar AB_1 by B_1B_2 $(= \lambda_1)$, the bar A B being shortened $BB_2 = \lambda_2$,

$$\text{so that } \lambda_1 + \lambda_2 = \lambda$$

The work done as the tension increases from 0 to T

$$\text{is } \tfrac{1}{2} T (\lambda_1 + \lambda_2) = \tfrac{1}{2} T \lambda,$$

E being the modulus of elasticity, and the tensions, lengths and sectional areas respectively of the necessary bars being

$$\begin{matrix} S_1 \, S_2 \, S_3 \\ l_1 \, l_2 \, l_3 \\ F_1 \, F_2 \, F_3 \end{matrix}$$

the work of deformation of the elastic forces—

$$A = \frac{T^2 l}{2 E F} + \Sigma \frac{S^2 l}{2 E F} = \text{minimum} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

this must be equal to the work due to the alteration of temperature, therefore

$$\frac{T^2 l}{2 E F} + \Sigma \frac{S^2 l}{2 E F} = \tfrac{1}{2} T \lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$(1) \text{ May be written } \left(\frac{T^2 l}{E F} + \Sigma \frac{S^2 l}{E F}\right) - \tfrac{1}{2}\left(\frac{T^2 l}{E F} + \Sigma \frac{S^2 l}{E F}\right) = \text{minimum}.$$

therefore from (2)

$$T \lambda - \tfrac{1}{2}\left(\frac{T^2 l}{E F} + \Sigma \frac{S^2 l}{E F}\right) = \text{minimum} \quad . \quad . \quad . \quad (3)$$

and differentiating

$$\lambda = \frac{T l}{E F} + \Sigma \frac{S \,.\, l}{E F} \cdot \frac{d S}{d T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This expression is put aside by Castigliano and others, with the remark that it might be used instead of the principle of least work of deformation in those cases where there are already strains in the elastic body before it is loaded. The proposition stated in (3) and (4) does not contradict the principle, but is derived from it. It has general application, and neither leads (as Professor Krohn maintains) to confusion, nor is there necessity to introduce the superfluous conception of "ideal work" (*ideelle Arbeit*). In the case of a number of supernumerary bars (3) becomes—

$$\Sigma \, T \, \lambda - \tfrac{1}{2} \left(\Sigma \frac{T^2 \, l}{E \, F} + \Sigma \frac{S^2 \, l}{E \, F} \right) = \text{minimum} \quad . \quad . \quad (3a)$$

Considering next a homogeneous body instead of a framework. If the temperature of a point x, y, z sinks t°, the length of the edges of the element of matter $dx \; dy \; dz$, supposing it free, decrease by $\lambda_x = a \; t \; dx$, $\lambda_y = a \, t \, dy$, $\lambda_z = at \; dz$, and the volume V by $a \, t \, d \, V$.

In consequence, however, of the elastic connection of element $dx \; dy \; dz$ with the surrounding elements normal strains $\sigma_x \; \sigma_y \; \sigma_z$ arise in its sides, lengthening the edges by

$$\lambda'_x = \frac{\sigma_x}{E} \cdot d \, x \qquad \lambda'_y = \frac{\sigma_y}{E} \cdot d \, y \qquad \lambda'_z = \frac{\sigma_z}{E} \cdot d \, z,$$

and the volume increased by

$$\frac{\sigma_x + \sigma_y + \sigma_z}{E} \, d \, V = (\lambda'_x + \lambda'_y + \lambda_z)' \, d \, V.$$

At the same time the normal strains $\sigma_x \; \sigma_y \; \sigma_z$ act on the sides of the surrounding elements of matter so that the edges of the parallelopipedon $dx \; dy \; dz$ are shortened respectively by λ''_x, λ''_y, λ''_z, the volume decreasing by $(\lambda''_x + \lambda''_y + \lambda''_z) \; d \, V$. The work of the normal strains increasing from 0 to σ_x, σ_y, σ_z respectively between the element $d \, x \; d \, y \; d \, z$ and the surrounding particle is—

$$\tfrac{1}{2} \, (\sigma_x \; d \, y \; d \, z) \, (\lambda'_x + \lambda''_x) = \tfrac{1}{2} \, (\sigma_x \; d \, y \; d \, z) \, \lambda_x = \tfrac{1}{2} \, a \, t \, \sigma_x \, d \, x \; d \, y \; d \, z$$
$$= \tfrac{1}{2} \, a \, t \, \sigma_x \, d \, V.$$

Similarly $\quad \tfrac{1}{2} \, (\sigma_y \; d \, z \; d \, x) \, (\lambda'_y + \lambda''_y) = \tfrac{1}{2} \, a \, t \, \sigma_y \, d \, V,$

and $\quad \tfrac{1}{2} \, (\sigma_z \; d \, x \; d \, y) \, (\lambda'_z + \lambda''_z) = \tfrac{1}{2} \, a \, t \, \sigma_z \, d \, V,$

and together $\quad \tfrac{1}{2} \, (\sigma_x + \sigma_y + \sigma_z) \, a \, t \, d \, V.$

Hence the work of the normal strains, due to change of temperature, working together in the body is—

$$A = \tfrac{1}{2} \int (\sigma_x + \sigma_y + \sigma_z) \, a \, t \, d \, V \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Now the general expression for the work of deformation (normal and shearing strains) in an elastic body is well known—

$$A = \frac{1}{2\,E}\int\left(\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - \frac{2}{m}\left(\sigma_y\,\sigma_z + \sigma_z\sigma_x + \sigma_x\,\sigma_y\right)\right) d\,V$$
$$+ \frac{1}{2\,G}\int(\tau_x{}^2 + \tau_y{}^2 + \tau_z{}^2)\,d\,V \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

By the principle of least work of deformation this must be a minimum, and it must be equal to the work due to difference of temperature (5).

Hence A from (6) + 2 A from (5) must be a minimum,

or $$\frac{1}{2\,E}\int\left(\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - \frac{2}{m}(\sigma_y\,\sigma_z + \sigma_z\,\sigma_x + \sigma_x\,\sigma_y)\right) d\,V$$
$$+ \frac{1}{2\,G}\int(\tau_x{}^2 + \tau_y{}^2 + \tau_z{}^2)\,d\,V$$
$$+ \int(\sigma_x + \sigma_y + \sigma_z)\,a\,t\,d\,V = \text{minimum} \quad . \quad . \quad (7)$$

This agrees with the expression proved by Müller of Breslau (page 211 "Zeitschrift des Architekten- und Ingenieur-Vereins," Hannover, 1884). It is evidently in close connection with the principle of the least real work of deformation, and there is no necessity for the introduction of the conception of "ideal work."

Considering finally cases concerned with statically indeterminate external forces (reactions), Professor Krohn considers that the principle of least work of deformation is only useful in cases where the equations for determining the unknown forces express the immovability of certain points of the framework (not, however, an elastic giving of the frame).

Let internal forces P_1 P_2 P_3 . . . act on points 1 2 3 . . . of a framework so that the points are moved Δ_1 Δ_2 Δ_3 . . . in the direction of the forces, the work done as the forces increase from 0 to P_1 P_2 P_3

is $$\tfrac{1}{2}(P_1\,\Delta_1 + P_2\,\Delta_2 + P_3\,\Delta_3\,.\,.\,.\,) = \tfrac{1}{2}\,\Sigma\,P\,\Delta \quad . \quad . \quad . \quad (8)$$

calling the strains hereby produced in the bars of the frame S_1 S_2 S_3 . . . the work of deformation of the internal forces is

$$A = \tfrac{1}{2}\,\Sigma\,\frac{S^2\,l}{E\,F} = \text{minimum} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

This work must be simultaneous with the negative work of the external forces, therefore from (8)

$$A = -\,\tfrac{1}{2}\,\Sigma\,P\,\Delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Hence (9) and (10) $\Sigma\,\frac{S^2\,l}{E\,F} - \tfrac{1}{2}\,\Sigma\,P\,\Delta = \text{minimum},$

or differentiating

$$2\,\Sigma\,\frac{S\,.\,l}{E\,F}\cdot\frac{d\,s}{d\,P_1}-\Delta_1-P_1\,\frac{d\,\Delta_1}{d\,P_1}=0\quad.\;.\;.\;.\;.\qquad(11)$$

Now as P_1 increase Δ_1 increases in proportion,

therefore $$\frac{d\,\Delta_1}{d\,P_1}=\frac{\Delta_1}{P_1},$$

hence (11)

$$\Sigma\,\frac{S\,.\,l}{E\,F}\cdot\frac{d\,S}{d\,P_1}-\Delta_1=0\quad.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\qquad(12)$$

Hence if the disturbance Δ_1 is known, the external force P_1 can be calculated.

Next in a homogeneous, weightless, originally straight beam A B C (A B = B C = l) to find the thrust at B which produces a deflection s. The moment of inertia J of the cross-section of the beam may be taken to be constant. The work of the internal forces $A'=2\,.\,\frac{1}{2\,E\,J}\int_0^l M^2\,d\,x=\frac{1}{E\,J}\int_0^l A^2\,x^2\,dx$, or since from the conditions of equilibrium $A=-\frac{B}{2}$

$$A'=\frac{1}{E\,J}\int_0^l\frac{B^2\,x^2}{4}\,d\,x=\frac{B^2\,l^3}{12\,E\,J}\quad.\;.\;.\;.\;.\;.\qquad(13)$$

The work of the external forces is

$$\tfrac{1}{2}\,B\,s,\ \text{hence}\ A'=-\tfrac{1}{2}\,B\,s\quad.\;.\;.\;.\;.\;.\;.\;.\;.\;.\qquad(14)$$

Hence by the principle

$$\frac{B^2\,l^3}{12\,E\,J}-\tfrac{1}{2}\,B\,s=\text{minimum}\ .\;.\;.\;.\;.\qquad(13)\ \text{and}\ (14)$$

therefore $$\frac{B\,l^3}{6\,E\,J}-\frac{B}{2}\cdot\frac{d\,s}{d\,B}-\frac{s}{2}=0;$$

or since B increases proportionately with s and $\frac{d\,s}{d\,B}=\frac{s}{B}$

$$\frac{B\,l^3}{6\,E\,J}-s=0,$$

hence $$B=\frac{6\,E\,J\,s}{l^3},$$

from which it is seen that the principle of least work of deformation holds in that case too, and may fairly be spoken of as universally applicable.

W. B. W.

The Question of Value-figures for Materials of Construction.

By Prof. R. KROHN, of Aachen.

(Civilingenieur, 1884, vol. xxx., p. 369.)

All recent writers agree that the work required to break a material is a measure of its value. If a curve is drawn with the specific extensions as abscisses and the specific stresses as ordinates, the area of the diagram is the work done on a body of unit section and length. For those materials, for which the stress increases till the extension attains a value δ, and then diminishes with increase of extension, the work up to the limit δ of the extension furnishes the value required. The diagram approximates to a straight line before the elastic limit is reached and a parabola beyond it. Consequently, if g is the load at the elastic limit, b the breaking-load, and δ the breaking-extension; the work done is

$$A = \delta\left[g + \frac{2}{3}(b - g)\right] = \frac{\delta}{3}(g + 2\,b) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If δ is taken per unit of length and b and g per unit of area, A is the work per unit volume. Consequently for a bar of length l and section F, the work to be done in fracture would be

$$F\,l\,A = F\,l\,\frac{\delta}{3}(g + 2\,b) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The Author then shows that the work done in breaking is not sufficient taken alone as a criterion of the value of a material. Thus for good wrought-iron, $g = 18$ and $b = 38$ kil. per square centimetre; $\delta = 15$ per cent. Consequently $A = 470$. But for copper, $g = 6$, $b = 20$, and $\delta = 36$ per cent.; so that $A = 552$. Hence the weak material copper appears by this test to be a better material of construction than wrought-iron—a conclusion to which no one would assent.

Tension-rod.—A bar of length l and section F hangs vertically and is fixed at its upper end. At its free end acts a steady load P. The extension due to this, since the elastic limit is assumed to be not exceeded, is small enough compared with the breaking-extension to be neglected. A falling load Q strikes the free end with a velocity due to the height of fall h. In general, part of the energy of the falling load is lost. The energy available for extension of the bar may be taken as

$$\frac{Q^2}{P + Q}\,h.$$

Suppose that by the action of the forces the bar is extended to the breaking-limit $\delta\,l$. The additional work done on the bar is then

$(P + Q)\,\delta\,l$. But the whole work done must be equal to the work in equation (2):—

$$\frac{Q^2}{P + Q}\,h + (P + Q)\,\delta\,l = F\,l\,\frac{\delta}{3}\,(g + 2\,b);$$

hence the required section of the rod is

$$F = 3\,\frac{Q^2\frac{h}{\delta\,l} + (P + Q)^2}{(P + Q)\,(g + 2\,b)}\,. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

The requirements of safety must, however, be satisfied. Let $(P + Q)\,/\,F = K$, where K is a stress less than the specific stress at the elastic limit, and for which a repetition of the loading does not cause fracture. If then K is given, the value of F just assigned can be introduced in equation (3). Then,

$$h = l\left(1 + \frac{P}{Q}\right)^2 \frac{\delta}{3\,K}\,(g + 2\,b - 3\,K)\,. \quad . \quad . \quad . \quad . \qquad (5)$$

The question of the value-figure for the material can then be answered. Obviously the best material is that which for equal section and length, and equal external forces, permits the greatest height of fall. The value is measured by the number

$$Z = \frac{\delta}{3\,K}\,(g + 2\,b - 3\,K).$$

The Author discusses this result, and also obtains a corresponding expression for a rod subjected to thrust.

W. C. U.

Bridge over the Gardon at St. Cécile d'Angorge.

By A. Charpentier.

(La Génie Civil, June 1883, p. 81.)

This bridge, which was built to carry the national road from Florac to Alais over the river Gardon, is of masonry, in one single span of 43 metres (141·04 feet) with a rise of 8·60 metres (28·20 feet), and 31·17 metres (102·23 feet), the radius of the curvature of the arch.

The width of the bridge between the iron railings, which serve as parapets, is 3·80 metres (12·46 feet), 2·50 metres (8·20 feet) being the width of the roadway, and 0·65 metre (2·13 feet) that of the two footways. The right abutment was built on rock, whilst the foundation of the left one was made on a compact gravel, and in order to prevent any danger of its being undermined by the scour of the current, it was protected on three sides by a double line of sheet piles 5 metres (16·40 feet) in length, and driven 1·50 metre (4·92 feet) apart, the ground between being excavated to a depth of 1·30 metre (4·26 feet), which was afterwards filled in with concrete.

The centering consisted of three ribs, each carried upon five supports, three of which rested upon a mass of concrete laid on piles driven into the river-bed for this purpose.

The thickness of the abutments is 11·50 metres (37·72 feet), and their height to springing 6·17 metres (20·23 feet), the total height from foundations to the level of the roadway being 16·67 metres (54·68 feet). The spandril walls are 1·25 metre (4·10 feet) in thickness, or about one-fifth of their total height, and in order to reduce their weight on the arch, ten openings 5 feet wide are left in each wall. The space left between the spandrils is arched over below the level of the roadway.

The construction of this bridge occupied 6 months, and its total cost was 69,000 francs (£2,760), or at the rate of 1,045 francs per metre run of structure (£12 14*s.* 11*d.* per foot run); 290 francs per square metre measured horizontally (£1 1*s.* 8*d.* per square foot), and 63 francs per square metre of vertical surface (£0 5*s.* 0*d.* per square foot.

P. L. N. F.

Bridge over the Schwarzwasser.

By Messrs. ROTHLISBERGER and SIMONS.

(Il Politecnico, April 1884, p. 239.)

The Authors state that, from the nature of the design and its lightness, this is one of the most remarkable bridges that have been erected in Europe of late years. The clear span between the abutments is 548 feet, the width of carriage-way 14 feet 6 inches, with two footways, each 2 feet 7 inches wide. The roadway is supported upon two abutments and twenty-eight iron piers, 20 feet apart. Eight of these piers (four at each end of the bridge) have masonry bases, the other twenty are supported by a wrought-iron arch of 374 feet span and 69 feet rise.

The Authors' design was chosen from a competition, of which the following were the conditions as to loading:—1st. Load uniformly distributed 61½ lbs. per square foot. 2nd. A four-wheeled cart, weighing 10 tons. 3rd. Wind-pressure 30¾ lbs. per square foot, at an inclination of 15°.

The weight and cost of the bridge were—

	Tons.	£.
Ironwork exclusive of Ω irons under roadway and parapet	354·37	6,800
Ω irons	55·10	592
Cast-iron parapet	13·77	432
Metalling		196
Masonry		1,400
Scaffolding		1,760
Total		11,180

Owing to the narrowness of the roadway there was a difficulty in obtaining sufficient lateral stiffness to resist wind-pressure, and it was therefore determined to spread out the ribs of the arch at the abutment to a width of 26 feet 3 inches, their distances apart at the crown being 17 feet.

The arch is composed of a pair of parabolic ribs of wrought-iron, which rest upon cast-iron bed-plates in the abutments. As these latter are simply masonry facings to solid rock, which cannot yield to the thrust, there is no doubt that this, and not a hinged bearing, is the right way of supporting the arch.

Each arched rib is formed of upper and lower flanges 5 feet 11 inches apart at the crown, 11 feet 6 inches at the springings. The flanges are of T section, and are connected by lattice-bars so constructed that there is an apex under each vertical pier, and one intermediate apex between each pair of piers, the apexes being equidistant upon a horizontal projection of the arch. Where each pier rests upon the arch the two ribs are braced together by lattice-work, and also by wind-bracing both at the upper and lower flanges.

The bridge was erected upon timber centres. First of all, the lower flanges of the two ribs were put together, resting upon wedges on the centres; then the lower wind-bracing was added for the purpose of regulating the lateral distance of the ribs. Then the upper flanges and the cross-girders between the arches were erected, working simultaneously from the two abutments; the whole was held together by bolts and trenails to the extent of 50 per cent. of the rivets, and the riveting-up was not done till the whole arch was in position. Wooden wedges, $\frac{3}{4}$ inch thick, were inserted between the stone bed-plates and the iron-shoes, in which the ends of the arch rested; and after the erection was finished, and a part of the metalling laid on, the spaces occupied by these wedges were filled with Portland cement.

To test the bridge, a load of ballast of half a ton per lineal foot was first placed over one-half of the bridge from one abutment to the crown. Afterwards a similar load was laid over the middle half of the bridge. A Table is given of the calculated and observed deflections, the greatest differences between these being slightly less than $\frac{1}{10}$ of an inch. A cart weighing ten tons was then taken across the bridge, but the deflections were so slight that they escaped the observation of four theodolites.

In designing the scaffolding, which was built up of round logs and planks, the principal point kept in view was to present as small a surface as possible to the wind. Four timber piers were erected across the valley, leaving spans of 65 feet 6 inches, and upon these piers the centering was constructed. The maximum strain on the wood was 426 lbs. per square inch. 17,658 cubic feet of round timber of the average diameter of 8 inches, and 17,222 square feet of $1\frac{1}{8}$ inch planks were used in the scaffold and centering, the section of the valley along the axis of the bridge having a surface of 71,000 square feet. Had square timbers been used a much larger amount would have been required.

The principal calculations of the bridge, and a graphic determination of the stresses, are given. In regard to wind-pressure, taking its force at 30¾ lbs. per square foot acting at an angle of 15°, the total overturning moment in respect to the base of the arch is 1,460 metre-tonnes. To oppose this is the total weight of the bridge, including the road metalling, 611·82 tonnes. One half of this acts with a lever arm of 8 metres (the distance between the two arch ribs at the abutments), and the amount of resistance opposed to the movement of wind-pressure is $\frac{611 \cdot 82}{2} \times 8$ = 2,447 metre-tonnes, or one and a half times the amount of the latter.

The weight per lineal foot of the 374 feet span is 17 cwt., and per square foot 1 cwt. exclusive of the Ω irons. The working-strain on the iron is 3·8 tons per square inch.

W. H. T.

Foundations of the Bridge over the Ticino at Sesto Calende.

(L'Ingegneria civile e le Arti industriali, vol. x., 1884, p. 65.)

The bridge over the Ticino at Sesto Calende is constructed not only for a double line of railway, viz., the line from Novara to Pino (one of the approaches to the St. Gothard's Tunnel), and the other from Milan to Arona, but also to carry the provincial road of the Simplon.

The total length between abutments is 840 feet, and consists of three spans, the central one being 325 feet. The usual practice of making the depths of the girders equal to $\frac{1}{10}$ of the span has been departed from in this case, and they have been increased to 11 metres (36·08 feet), taking into consideration there being a double line of rails, and also a roadway 8 metres (26·25 feet) to be supported.

This carriage-road is placed at a height of 5·50 metres (18·04 feet) above the level of the rails, and that in order to reduce to a minimum the gradient and length of the approaches.

In consequence of the nature of the ground, a sandy clay, and of the depth of water, which in the middle of the river is 8 metres (26·25 feet), it was necessary to adopt the pneumatic method for excavating the foundations. The caissons were made similar in form to those used for the bridges over the Po. The height of the underside of the girders being 201·70 metres above the sea-level, whilst that of low water is 192·80, the height of the piers and abutments above the water-level is 8·90 metres (29·20 feet).

The total heights are as follows:—

—	Total Height.	Depth below Water Level.	Depth Sunk.
	Metres. Feet.	Metres. Feet.	Metres. Feet.
Right abutment . . .	16·82 = 55·17	7·62 = 24·99	8·82 = 28·93
„ pier.	29·70 = 97·41	20·80 = 68·22	14·40 = 67·23
Left pier	26·21 = 85·97	17·31 = 56·77	16·81 = 55·13
„ abutment . . .	23·82 = 78·13	14·92 = 48·93	17·12 = 56·15

The material excavated was removed in wrought-iron buckets holding 0·30 cubic metre (0·39 cubic yard) each, and hoisted by a small three-cylinder engine worked with compressed air, placed above the air-locks, and discharged through a pipe provided with suitable doors. The excavation under pressure was carried on without interruption by two gangs of workmen in shifts of eight hours each, and it was only during the last few days of sinking the right pier, and when the normal pressure of two atmospheres had to be increased to 2·8 atmospheres, that the shifts were reduced to six hours, and later to only four hours each.

Each gang was composed of twenty-five men, of whom fourteen were engaged in the working-chamber for excavating and loading the buckets, six in the two air-locks for discharging the material and working the doors, and the remaining five outside for working the outer doors, removing the material, and attending to the machinery.

The air was supplied by two direct-acting compressors, driven by two semi-portable engines of 15 HP. each. They were entirely independent of each other, and communicated separately with the two air-locks.

The interior of the working-chamber was lighted at first with candles, but subsequently electric light was adopted. This gave most satisfactory results, and especially in sinking the two last foundations, which were lighted for five hundred and fifty consecutive hours without any difficulty. The lights used were eight-candle power Swan's incandescence-lamps, eight being fixed in the working-chamber, one in each of the air-locks, and a sufficient number outside. The current was supplied by a Siemens dynamo, driven by a portable engine. The two conducting copper wires from the engine-shed to the caissons were fixed in the ordinary way into porcelain insulators, and pass through the iron-casing of the air-lock by means of a brass plug lined with ebonite; within the air-lock and interior of the working-chamber this wire was coated with insulating material, and as an additional precaution was contained in an india-rubber tube.

The material through which the caissons were sunk consisted for the greater part of a fine sandy clay, which increased in compactness with the depth. The sinking was, generally speaking, attended with very little difficulty until the last, when, on account of the great adhesion of the clay against the sides of the caisson, and notwithstanding the ground being excavated from under it, it remained suspended, and it was found necessary to increase the pressure by $\frac{1}{2}$ and even $\frac{7}{10}$ to $\frac{8}{10}$ of an atmosphere, in order that the air continually escaping from the working-chamber at the cutting-edge up the outside of the caissons, neutralized to a great extent the friction of the ground, and then, by adding as much weight as possible and suddenly reducing the pressure, the caisson descended freely.

The depth sunk daily was very variable, but may be taken to average 2 feet, which would represent about 65 cubic yards of excavation every twenty-four hours. In order to resist deformation during the process of sinking, the caissons were strengthened by iron bracings, and the bottom edge by four strong beams.

For the purpose of sinking the caissons, a temporary timber scaffolding and staging, resting upon poles driven into the bed of the river, was erected and furnished with all the necessary hoisting-tackle for raising and lowering the air-locks, &c.

The first caisson was put down on the 7th October, 1881, and the last was in place on the 20th June, 1882. The number of days employed in sinking the different caissons was: left abutment, thirty-nine days; left pier, sixty-three days; right pier, forty-eight days; right abutment, twenty-seven days.

The caissons were filled with concrete compounded of broken granite from the Lago Maggiore quarries, and hydraulic mortar made with Palazzolo lime, the concrete from the roof of the working-chamber to top of caisson being filled in first. The working-chamber was filled up afterwards, the concrete being passed down through the air-locks in pipes, and was well rammed in up to the roof. The air-lock shaft was then unbolted, and the water rose through slowly to the level of the river in the spaces left in the masonry, which were afterwards filled in under water with concrete.

The masonry above the foundations was executed in Lago Maggiore granite and mortar of Palazzolo lime, the face-work being in dressed blocks of red granite from the quarries of Baveno. The blocks upon which the girders rest are of white granite from the quarries in the neighbourhood of Feriolo and Baveno, about 5 metres (176·58 cubic feet) each.

The foundations for the wing-walls of the abutments were excavated in the usual manner. The bottom was consolidated with piles 12 inches diameter, and 32·80 feet in length. A gridiron of timbers being bolted to the pile tops, and the whole filled in with concrete to a depth of 1·75 metre (5·75 feet), and upon this floor two courses, 25 centimetres (10 inches) in thickness of granite blocks was laid, and upon this masonry, similar to the piers in white and red granite was built. As it was feared that an unequal settlement might take place between the abutments and wing-walls, the masonry of each was carried up to the full height entirely independent of the other, but without the granite face-work, which was not completed until sufficient time had been allowed for settlement, and until after the girders were in place.

P. L. N. F.

Widening the Austerlitz Bridge, Paris.

(Le Génie Civil, Nov. 22, 1884, p. 50.)

This bridge was built in the years 1802–5, and consisted of five cast-iron segmental arches of 106 feet 2 inches span, with masonry piers and abutments founded on piles and timber platforms. The total length between the abutments was 570 feet, and the width between the parapets 42 feet 6 inches. In 1854, the bridge being no longer equal to the requirements of the traffic, it was determined to widen it. It was found that the cast-iron arches had not given satisfactory results, but were displaced and broken in places. They were, therefore, replaced by stone arches; the bridge being thus increased in width to 59 feet. The piers of the original bridge were 59 feet wide, and were, therefore, wide enough to support the new arches, cutwaters only being added to them, which were built upon rockwork, surrounded by piling, and filled in with concrete, which formed part of the old work.

Since 1854 the traffic over the bridge has increased to such an extent that it has been necessary to widen it again, so as to give a carriage-way of 65 feet 6 inches, and two footways of 16 feet 6 inches each. The foundations for the additional width required for the abutments are on piles, which are placed 3 feet 3 inches apart, from centre to centre. Each pile is 1 foot square, and driven as far as it will go. The earth is excavated to a depth of 4 feet 3 inches below the pile-heads, and filled in with masonry in cement. The circular wing-walls are founded in the same manner. The pier-foundations are executed by means of wrought-iron caissons, 23 feet 3 inches by 19 feet. Each caisson is divided into two compartments by a horizontal platform, 6 feet 6 inches above the bottom. The lower division is the working chamber. In the upper the masonry is built up as the sinking progresses, and when the bottom is reached, the earth is all excavated from the lower division, which is then filled up with masonry in cement, driven well home against the sides and roof of the chamber.

The height of the abutments from the foundation of the masonry to the springings is 23 feet; their thickness is 32 feet 9 inches. The height from the foundation of the piers to the top of the highest footing is 11 feet 6 inches; thence to the springing 18 feet. The thickness of the piers is 10 feet 2 inches at the springing, and 11 feet 2 inches above the footings.

The new arches are built up to the old, but not joined to them.

The spans and versed sines vary slightly, the means being 105 feet 10 inches, and 14 feet 3 inches respectively; the thickness at the crown is 4 feet 1 inch, and at the springing 4 feet 9 inches. The slackening of the centres will be effected by sand-boxes.

Underneath each footway are two galleries, one 5 feet 7 inches wide and 4 feet 1 inch high for water-pipes; the other 4 feet 9 inches wide and 4 feet 1 inch high for gas pipes. These are separated by a brick wall 1 foot 2 inches high, and arched over with a ring of 4-inch bricks.

W. H. T.

Erection of a Concrete Bridge in One Day.

(Schweizerische Bauzeitung, Nov. 29, 1884.)

The firm of Zurlinden and Co. of Aarau, having constructed a canal in connection with their works about ⅔ mile in length, were obliged by the town authorities to bridge it in two places. This they did by means of segmental arches of cement concrete, constructed to the designs of Professor Tetmajer of Zürich. The dimensions of the arches are:—

	Metres.	Ft.	In.
Span	12·00	39	4
Rise	2·00	6	6¾
Thickness at crown	0·50	1	7¾
„ „ abutment	1·00	3	3½
„ of abutments . . .	3·00	9	10
Width of roadway	4·00	13	1½

The foundation of both abutments is on fairly good gravel, at a depth of about 5 feet below the springing. Spandril walls are carried up to the level of the roadway, and surmounted by an iron hand-rail, the space between the spandril walls being filled in with gravel covered with ordinary road metalling. The total weight of the structure between the abutments is 194 tons, or, including a live load of 300 kilograms per square metre (61·5 lbs. per square foot) 211 tons. The first bridge was erected in two days in June 1884, the two abutments being formed on the first, and the arch and spandril walls on the second day. The bridge was brought into use after standing for two months, and has been in constant service ever since for heavy-wheeled traffic without any sign of settlement or cracking.

On the 9th of October the second bridge was completed between 6 A.M. and 6 P.M. by sixty-five men.

The concrete was mixed in accordance with the recommendation of Professor Tetmajer as follows: The cement and sand were first mixed dry, then the gravel added, water being gradually added during the mixing in such quantities that when the punning of the concrete was completed a thin film of water showed upon the surface. The concrete was mixed as follows:—

—	Cement Vol.	Sand Vol.	Gravel Vol.	Pounds of Cement per Cubic Yard of Concrete.
Abutments	1	3	7	337·2
Arch	1	2	4	505·8
Spandrils	1	2	6	421·5

The cost of such a bridge is given as—

	£.	s.	d.
Excavation 50 cubic metres (65 cubic yards) at 10*d.*	2	1	8
Concrete (including centering, &c.) 80 cubic metres (104 cubic yards) at 25*s.*	100	0	0
Filling-in over arch, forming road	8	6	8
Iron hand-railing	10	8	4
	£120	16	8

W. B. W.

The Railways of the World. By PAUL TRASENSTER.

(Cours de Géographie industrielle et commerciale à l'École des mines de Liège.)

The following statement is taken from one prepared by Mr. Paul Trasenster, for the instruction of the students of the École des Mines de Liège. It is said to be the most complete, and also the most correct, statement yet compiled of the railway mileage of the world. The original is given in kilometres, which are here reduced into English statute miles omitting fractions. The distances for 1882 are complete, and those for 1883 are given as far as was known to the Author at the date of publication :—

Countries.	Miles of Railway open.	
	1882.	1883.
EUROPE.		
Germany	21,692	22,260
Great Britain	18,457	18,681
France	17,755	18,256
Russia	15,160	..
Austria-Hungary	12,406	13,045
Italy	5,720	5,810
Spain	4,866	5,236
Sweden and Norway	4,808	..
Belgium	2,656	..
Switzerland	1,775	..
Holland	1,219	..
Roumania	912	..
	107,426	Carried forward.

Countries.	Miles of Railway open.	
	1882.	1883.
Brought forward	107,426	
Turkey	864	..
Denmark	1,082	..
Portugal	938	961
Luxemburg	264	..
Greece	8	53
Total for Europe	110,582	..
ASIA.		
British India	10,126	..
Ceylon	177	..
Java	380	..
Asia minor	308	..
Japan	138	175
Total for Asia	11,129	..
AFRICA.		
Egypt	941	941
Algeria and Tunis	1,153	1,172
Cape	959	..
Natal	99	155
Mauritius	82	..
Reunion	71	..
Total for Africa	3,305	..
AMERICA.		
United States	114,838	121,592
Canada	7,516	..
Mexico	2,225	2,883
Costa Rica	124	..
Nicaragua	35	..
Guatemala	28	..
Honduras	56	..
San Salvador	10	..
Cuba	874	..
Porto Rico	8	..
Jamaica	25	..
Trinidad	43	..
Columbia	107	..
Venezuela	70	92
British Guiana	21	21
Brazil	3,016	..
Argentine Republic	1,626	1,799
Paraguay	45	..
Uruguay	181	..
Chili	1,177	..
Peru	1,148	..
Bolivia	81	..
Ecuador	31	76
Total for America	133,285	..

Countries.	Miles of Railway open.	
	1882.	1883.
AUSTRALASIA.		
New South Wales	1,312	..
Victoria	1,353	..
South Australia	943	..
Queensland	865	..
West Australia	94	..
Tasmania	166	..
New Zealand	1,462	..
Total for Australasia	6,195	..
Total for World	264,496	..

F. R. C.

The Railway-System of the United States.

(From the Seventeenth Annual Number of the Manual of the Railroads of the United States.)

The length, cost, earnings, and dividends of the railroads of the United States are annually given, in careful detail, in the manual drawn up by Messrs. Poor. From the number for 1883, the following figures have been abstracted; converting the American reckoning in dollars and cents into the English terms of £ *s. d.* In a parallel column are shown the corresponding figures for the railways of the United Kingdom for 1883, so far as it possible to obtain them from the railway returns. The receipts per passenger-mile, and per ton-mile of freight, are not attainable on the English railways.

	United States.	United Kingdom.
Miles of railway	121,592	18,681
Total capital	£1,499,094,262	£784,921,312
Cost per mile	£12,435	£42,017
Miles laid per annum	2,251	346
Gross revenue	£164,755,000	£71,062,000
Revenue per mile	£1,354	£3,803
,, ,, cent. on capital	10·99	9·15
Working cost	£97,372,628	£37,368,562
,, ,, per mile	£600	£2,000
,, ,, ,, cent. of revenue	58·8	53
Net revenue	£67,382,373	£33,693,708
,, ,, per mile	£554	£1,803
,, ,, ,, cent. on capital	4·49	4·29
Receipts per passenger train-mile	4·44*s.*	4·26*s.*
,, ,, goods ,, ,,	6·24*s.*	6·03*s.*
,, ,, mile of road; passengers	£353	£1,579
,, ,, ,, ,, freight	£1,001	£2,224
,, ,, passenger-mile	1·21*d.*	..
,, ,, ton-mile of freight	0·618*d.*	..

Out of the total capital of nearly 1,500 millions sterling, it is estimated by Messrs. Poor that at least 200 millions sterling represents fictitious capital, created within the last four years. In 1879 the average cost of a mile of American railway was £11,546; and the length of line constructed since 1879 is stated by Messrs. Poor to have cost less than that rate per mile; so that the price per mile given in the Table is raised by the issue of capital in question.

F. R. C.

The Consumption of Sleepers on French Railways.

By H. Mathieu.

(Revue Générale des Chemins de fer, May 1884, p. 229.)

The object of the Author is to ascertain the situation in France in respect of transverse sleepers of wood, the annual consumption of such sleepers, the means of maintaining the supply, and the different kinds of wood used for sleepers; to ascertain, moreover, whether the exclusive use of wood for sleepers should be continued. Iron sleepers, though used extensively in Belgium and in Russia, are but little used in France, and have only been used experimentally as yet.

From the returns of the six great railway companies in France for the five years 1878 to 1882, it appears that the average annual consumption amounted to 2,749,292 sleepers on 12,720 miles, average length of line open, or 18,660 miles of single way: at the rate of 147 sleepers per mile of single way. Sleepers of oak are the most common, constituting two-thirds of the whole number; beech sleepers constitute one-fifth; next come those of pine and pitch-pine, about one-ninth; and, lastly, sleepers of fir, constituting little more than 1 per cent. of the total number. If an allowance of 25 per cent. of the total length of single way be made for lines at stations, the total length of single way laid for all purposes amounts to 23,325 miles, and the consumption of sleepers to 118 per mile of way. The annual rate of consumption varies with the kind of wood used. The Eastern and Orleans railways, on which four-fifths of the sleepers are of oak, show the lowest rate of consumption, whilst the Southern Railway, on which two-thirds of the sleepers are of pine, shows the highest rate of consumption. But, on the contrary, the cost for new sleepers on the Southern Railway is very little more than the average for the other lines. During the five years already noted the average annual cost for new sleepers amounted to about £30 per mile.

In applying the foregoing data to the entire system of railways in France, of which there were, on the 1st of January, 1883, a total length of 30,980 miles, the estimated total consumption of sleepers amounts to 3,618,400 for the year 1883. For the year

1896, when the railway system will be completed, there will be required, for maintenance only, 4,918,400 sleepers, of which the forests of France may supply 4,000,000, leaving the remainder to be imported from foreign countries.

The Author concludes with the observation that, in his opinion, the trials of metallic transverse sleepers that have hitherto been made have not yet led to a satisfactory solution of the problem, and that they should be continued.

D. K. C.

Technical Report of the German Railway-Union.

(Organ für die Fortschritte des Eisenbahnwesens in technischer Beziehung. Organ des Vereins deutscher Eisenbahnverwaltungen, Herausgegeben von Edmund Heusinger von Waldegg. Neunter Supplementband. 4to., 414 pages and 27 plates. Wiesbaden 1884.)

The ninth supplement to the annual volume of the Organ of the German Railway-Union has been published, giving the results of the Conference of railway experts held at Danzig in July 1884. The proceedings of the Conference are divided into eight groups, and each group is sub-divided into sections. In the present instance Group I., relating to way and works, is the most important, and constitutes 106 pages, or more than one-fourth of the whole volume, the principal subject considered being metallic permanent way; but space is also devoted to rails, sleepers, fastenings and connections, road-bed and drainage, maintenance of the superstructure, bridges and culverts, and tunnels. In succession come Group II., works at stations (64 pages); Group III., locomotives and tenders (81 pages); Group IV., carriages and wagons (35 pages); Group V., construction and management of shops (17 pages); Group VI., service of way (17 pages); Group VII., service of trains (57 pages); and Group VIII., signals (27 pages).

The report is too long to be usefully abstracted, but an idea of its completeness and elaboration of detail may be had by reference to the Minutes of Proceedings, vol. lvii., p. 208, which gives a summary of the conclusions arrived at at a similar Conference held in 1878.

F. G. D.

Steam Tramways at St. Étienne. By E. BERTHIER.

(Le Génie Civil, Nov. 29, 1884, p. 69.)

These tramways are laid in a very hilly district, and have gradients of 1 in 14 and curves of 1 chain radius. Ever since their construction they have been worked by steam, for the first two years under provisional, since then by definite approval of the authorities. The rolling stock consists of thirty-four locomotives and one hundred and nine carriages. There are three lines, having a total length of 24 miles; the gauge is 1 metre. The Bellevue-Terasse line is 3⅓ miles long; the total ascent is 262 feet, the steepest gradient 1 in 35. The line is single, with eight passing places (including the two termini). The points are automatic; each train consists of three or four carriages; six trains per hour are run each way; there are six stopping places; the speed is limited by the specification to 12½ miles per hour, but is actually 7¾ miles while running, or 6 miles including stoppages. In the middle of the town the waste steam is condensed.

The town of St. Étienne contains about 124,000 inhabitants. The number of tram passengers in 1883 was 4,248,371, or an average of thirty-four journeys per inhabitant. The corresponding figure in Paris is 90 (by omnibus); in St. Petersburg, 62 (trams); in Brussels, 40; in Rouen, 50; in Havre, 31; in Lille, 22; in Nantes, 18. The fare for the journey of 3½ miles is 10 centimes.

The St. Étienne-Firminy line is 6 miles long with an ascent of 288 feet; the steepest gradient 1 in 16. There are two trains per hour each way; there are three passing and fifteen stopping places. The running speed is 10 miles per hour, or, including stoppages, 7 miles.

The rail used is Demerbe's system, weighing 60½ lbs. to the yard. At first they rested on the ground, being simply packed with ballast, but it has been found necessary to lay the rails on transverse oak sleepers.

The engines used at first were those of Brown, built at Winterthur. These have the cylinders placed above the frame to keep them free from dust and within reach of the driver, but they were not found satisfactory; the centre of gravity was too high and caused very objectionable rocking; the load per axle was too high, there being only four wheels; the boilers, on the other hand, were well made and economical.

The engines now used are Carels' (of Ghent). These are running on the line with the steepest inclines, and have given satisfaction. They have six wheels, coupled, of which the central have no flanges. The cylinders are 10⅝ inches in diameter, 13¾ inches stroke; the weight is 12 tons empty and 15 tons when running. Other details are given. The regulator and reversing lever are in duplicate, so that the engine can be driven from either end, as they are never turned.

The carriages are designed to carry thirty-two passengers, all inside. Their length varies from 18 to 21 feet; their width over all is limited to 6 feet 7 inches, and height to 13 feet 1½ inch. They weigh from 2½ to 3 tons.

The consumption of coke per engine-mile is 14¾ lbs.; that of coal for lighting up ½ lb., oil 0·06 lb., grease 0·03 lb.

The cost of traction is as follows:—

	Per Engine-Mile.	Per Carriage-Mile.
	d.	d.
Fuel	2·33	0·89
Oil and grease	0·49	0·18
Lighting	0·05	0·02
Repairs	2·05	0·78
Water	0·06	0·02
Drivers and stokers — Fixed pay	2·50	0·96
Drivers and stokers — Premiums for economy	0·17	0·06
Total	7·65	2·91

To the above must be added for each carriage—

	d.
Oil and grease	0·02
Lighting	0·02
Repairs and cleaning	0·32
License	0·20
Collection	0·70
Total	1·26

The cost per mile for a train of three carriages is therefore—

	d.	d.
One engine at	7·65	7·65
Three carriages at	1·26	3·78
Total		11·43

The cost, including general expenses, &c., is—

	Per Engine-Mile.	Per Carriage-Mile.
	d.	d.
Administration and general expenses	4·67	1·79
Maintenance of way, pointsmen, &c.	0·72	0·27
Collection and control	2·28	0·87
Engines as above	7·65	2·91
Carriages as above (except collection)	1·47	0·57
Total	16·79	6·42

The average train consists of an engine and 2·6 carriages. The mean daily journey of an engine is 68 miles.

W. H. T.

Experiments on the Flow of Water over Submerged Weirs.

By James B. Francis.

(Transactions of the American Society of Civil Engineers, 1884, pp. 303–312.)

The ordinary formula for a drowned weir is,

$$Q = \tfrac{2}{3}\, c\, l \sqrt{2\, g}\, (H_2 - H_3)^{\frac{3}{2}} + c\, l\, H_3 \sqrt{2\, g\, (H_2 - H_3)}.$$

where Q is the discharge per second; l the length of the weir; H_2 head above crest, on up-stream side; H_3 head above crest, on down-stream side. The experiments lead to the formula for a weir with no end-contractions,

$$Q = 3{\cdot}33\, l\, (H_2 - H_3)^{\frac{3}{2}} + 4{\cdot}5988\, l\, H_3 \sqrt{H_2 - H_3},$$

or more simply

$$Q = 3{\cdot}33\, l \sqrt{H_2 - H_3}\, (H_2 + 0{\cdot}381\, H_3).$$

If there are n end-contractions $l - 0{\cdot}1\, n\, H_2$ is to be substituted for l.

The results are compared with the Fteley and Stearns formula, which is found to agree very closely with the discharges measured. W. C. U.

Canalization of the River Main from Frankfort to Mainz.

By — Düsing.

(Zeitschrift des Vereines deutscher Ingenieure, Oct. 25, 1884.)

The Main is to be made into a canal, with a uniform depth of 2·50 metres (8 feet 3 inches), by means of weirs and locks. The nature of the river and its banks makes it peculiarly suitable for this treatment. In the plan which is now being carried out, there are five weirs at Frankfort, Höchst, Okriftel, Raunheim, and Kostheim. At each of these places there is on the left bank of the river a side-canal with a lock for ships, and on the right bank a channel for rafts.

The following are the measurements at the various stations:—

—	Height of Weir.	Length of		
		Raft-Channel.	Upper Canal.	Lower Canal.
	Feet.	Feet.	Feet.	Feet.
1. Frankfort . . .	8·85	1,312	1,968	1,312
2. Höchst	5·90	656	328	1,312
3. Okriftel	5·90	656	328	1,312
4. Raunheim . . .	5·90	656	328	1,148
5. Kostheim . . .	8·85	984	328	3,937

The side-canals have a depth of 8 feet 3 inches, with a width at bottom of 65 feet 8 inches, and slopes of 1½ to 1. Below the water-level there is a benching 3 feet 3 inches wide on each side, and 3 feet 3 inches above the surface of the water a towing-path about 13 feet wide. The locks have an available length of 262 feet 6 inches, the clear width being 34 feet 5 inches, and the depth of water over the sills 11 feet 6 inches, so that the largest Rhine vessels can go through. In view of the possible introduction of chain-haulage on the Main, the lower canals are all made straight; and it is proposed to make such provision in the lower canals that the locks may be increased in length by about 1150 feet, so that whole towing-fleets may pass through at once.

The bottom of the locks is of trass concrete, with paving in cement-mortar, and the masonry is of sandstone, with basaltic lava for the more important parts. The gates are of oak, and are fitted with sluices.

Movable weirs on Poirée's needle-weir[1] system have been chosen on account of the nature of the Main, and the increase of building in the valley. The weirs are from 328 to 574 feet wide, according to the local conditions, and can be laid down entirely in case of floods or passage of ice, so that the whole cross-section of the river is free. Besides being used in France, these weirs have been used in Germany on the Saar, the Moselle, and the Lower Brahe. The weirs can be let down in from one to one and a half hour. A passage on the cascade-system for fish is made at the left bank. At the right bank is the channel for rafts. This is 39 feet 4 inches wide at the bottom; the length varies with the local conditions. The sides and bottom are pitched.

The estimated cost of the works is—

	£.
Frankfort	74,750
Höchst	46,600
Okriftel	41,960
Raunheim	46,360
Kostheim	52,795
General charges, telegraph, &c.	12,535
Total	275,000

It is expected that with favourable weather, the canalized navigation will be opened on October 1, 1886. W. B. W.

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[1] Minutes of Proceedings Inst. C.E., vol. lx., p. 30.

An Open Canal through "Holland op zijn Smalst."

By Prof. A. Huet.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1884, p. 213.)

The Author enumerates the different proposals made from time to time for a canal through the Isthmus of Holland between the sea-arm of the Y near Amsterdam and the North Sea.

He divides these proposals into four groups: First, those intended for facilitating the drainage of the surrounding district. Second, those for navigation, and in which the fairway from Amsterdam is laid through the Y. Third, those laid through the land leaving the sea-arm unreclaimed; and Fourth, those proposing to utilize the Y as part of the system, and making a canal with an open fairway without locks from the North Sea to the Zuiderzee.

This last system is more especially investigated, and the two principal projects to this effect, one by A. Caland, the second by T. Lankelma, both of 1868, are analyzed. He also mentions a former proposal of the same nature by himself, which was discussed at a meeting of the Institute of Engineers of the Netherlands in 1863. An extensive review is given of the different opinions given for and against these plans, with regard to the influence of the flow of the tides in an open channel, on the depths to be maintained, and quoting opinions given at the time as to the prudence of leaving the Suez Canal without locks. The Author concludes that an open channel would have been preferable to the present canal, with locks, based on the views enunciated by some of the most eminent engineers.

He arrives at the conclusion that the most desirable way to ensure for Amsterdam an increased commercial transit, will be to alter the present canalized waterway into an open fairway, through which the waters of the Yssel and of part of the Nether Rhine could flow to the sea, and which would also facilitate the reclamation of the Zuiderzee.

H. S.

The Sea-level on the Dutch Coast. By J. J. Roelants.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1884, p. 215.)

The Author compares the observations of the high- and low-water levels during eighteen years, at six stations in the Netherlands, and concludes that no tendency is shown for the rising or falling of the mean sea-level, compared to the elevation of the coast above the sea during the period under observation; so that, so far, no confirmation is found for the opinion of some writers. who hold the theory of a gradual subsidence of the east coast of the North Sea.

The Paper is accompanied by a drawing.

H. S.

The New Maritime Station at Dunkirk. By — COSSMANN.

(Le Génie Civil, 19th July, 1884, p. 185.)

Dunkirk is the fourth in order of magnitude of the French ports. Its trade has increased 70 per cent. in the last ten years. During 1883 the foreign imports were 1,244,517 tons, coasting imports, 78,323 tons; the foreign exports were 114,654 tons, coasting exports, 144,493 tons; the total exports and imports being 1,581,987 tons.

The works at present in course of execution comprise; 1st, the improvement of the entrance to the harbour by dredging and the prolongation of the western jetty. The depth is to be 10 feet at low water of spring-tides, so that at flood-tides vessels drawing 20 to 23 feet will be able to enter. The increase of 330 feet in length of the western jetty is intended to shelter large vessels from the current which runs from west to east at the entrance to the harbour. 2nd. Increase of floating basins and quays, the former from 40 to 47 acres, while the length of quays will be 20,000 feet, the principle of construction being that the quay-space for vessels to lie against shall be greater than the open space in the basins, and that the moles separating the latter should have a width equal if not superior to the water-space between them. 3rd. Enlargement of the entrance dock. 4th. Installations for building and repairing ships.

The port is the only one in France in which the railway lines and station have been systematically laid out for loading and unloading ships and sorting the trains. The leading idea in laying out the lines was that the basins of the harbour should be regarded as a goods yard in which the ships took the place of carts; and with this view the quays should be provided with lines of way laid down with the special object of facilitating loading and unloading, and connected with the main lines in the main station, at which the sorting of the wagons should be carried on. For instance, mole No. 1, lying between docks 1 and 2, is 560 feet wide, nearly double the width of each of the docks, and a cross-section of it would show: 1st, at 4 feet 3 inches from the edge of the quay a line of way of the normal gauge for the travelling cranes intended for loading and unloading goods. 2nd. At the side of this line, another for the wagons in course of loading to stand on. 3rd. A space reserved for the erection of sheds or warehouses, for the reception of such merchandise as is not forwarded direct to its destination; this space is provided with a cart road. 4th. A set of five parallel lines of railway, the first for full, the second for empty wagons, the third for arrival trains, the fourth for departure trains, the fifth for the engine traffic. The five lines of way are connected by rectangular cross-overs and turn-tables, and by a cross-over road with slip-points to each line. 5th. In the centre of the mole a track 200 feet wide, consisting of two cart roads each 50 feet wide, and between them a space for warehouses and stores. 6th. At the other side of this space similar lines of way, &c., to those above described.

The series of lines serving the different moles communicate with a principal line running parallel to the main line and forming a junction with it for each mole. Thus each basin forms as it were a local railway station. The passenger and goods station at Dunkirk is treated also as a local station, and the trucks coming to or leaving these several stations are mustered at the sorting-station at which the work of classifying the material sent to and coming from different quays is carried out. It is, so to speak, the pulsation of this central and indispensable organ which keeps in regular order the work of the whole extent of the port. The lines coming from the harbour branch out into fifteen parallel sidings having each an effective length of about 1,300 feet and communicating at the other end, by means of a suitable arrangement of points, with the main line to Paris. There are also fifteen lines of sorting-sidings worked by gravitation.

It is estimated that from four to five thousand wagons each way can be dealt with at this station, so that, allowing a load of only 3 tons to each wagon, and reckoning three hundred working days in the year, the accommodation is sufficient for traffic of from 4 to 5 million tons a year.

W. H. T.

Madras Harbour. F. N. THOROWGOOD, M. Inst. C.E.

(Roorkee Professional Papers, July, 1884.)

The coast of Madras at the site of the harbour, and for miles north and south of it, is low and flat, the town being only 7½ feet above high water. The rise and fall of tide is 1 foot at neap- and 3 feet 11 inches at spring-tides. From January to March the wind is N.W. to E.N.E. and the current from N. to S. In May and June the wind is E. or W. according to the time of day. In April and from July to October the wind is S. of E., and the current from S. to N. From October to December the wind is N.E. to N., and the current runs from N. to S. The stormy season is from October to December. The current runs from 1 to 3 miles per hour.

The harbour was designed by Mr. W. Parkes, M. Inst. C.E. There are two breakwaters at right angles to the coast and 3,000 feet apart. At a distance of 2,500 feet from high water-mark on shore these curve inwards, making an angle of 112° with their former direction, and approaching one another till their ends are 250 feet apart. The area thus enclosed gives 170 acres, with a depth of from 3 to 7½ fathoms, and 40 acres with a depth of less than 3 fathoms. The depth at the entrance is 8 fathoms.

The lower portion of the breakwater is formed of a bank of loose rubble 79 feet wide at the top with slopes of 1 to 1, the top being 22·6 feet below mean sea-level. The superstructure consists of a wall of concrete blocks, two blocks wide and four high. The bottom blocks are 14 feet wide, giving a total width of base of 28 feet, and they weigh 22½ tons each. The upper blocks, weighing 27 tons, are 4 feet 6 inches by 12 feet by 8 feet, giving a width of 24 feet. All the blocks are set with a batter of 3 inches per foot towards the end of the breakwater, and are not fastened or bonded in any way to the adjoining blocks, except that on the top side of each block there is a joggle 2 feet by 13½ inches at one end tapering to 2 feet at the other end, and this fits (with 3 inches play) into a corresponding recess in the underside of the block above. The piers thus consist of two contiguous rows of piles of concrete blocks, each pile consisting of four blocks, and each capable of settlement without disturbing its neighbours.

The materials used in making a 27-ton block were-

	T.	C.	Q.	lbs.
Portland cement	2	0	0	8
Sand	4	13	2	24
Crushed stone	13	15	2	24
Lumps of stone, handset	4	4	2	16
Water	1	15	2	24
Total	26	9	3	12

The cost of the blocks was 16*s.* 3*d.* (R. = 1*s.* 10½*d.*) per cubic yard. They were set by means of a Titan crane, the surface being prepared by divers for the bottom blocks. The cost of setting them was from 3*s.* 5½*d.* to 3*s.* 0½*d.* per cubic yard.

The length of the superstructure of the N. pier is . . 3,866 lineal feet.
" " " " S. pier is . . 3,970 "
The number of concrete blocks set was 13,304 . . =202·343 cubic yards.

Details are given of the manner in which the various portions of the works were carried out, and of the damage sustained by the breakwaters in the storm of 12th November, 1881, shortly after their completion.

W. B. W.

Is the Destruction of Forests a Cause for the Increase in the Frequency and Height of Floods? By T. P. Roberts.

(A Paper read before the Engineers' Society of Western Pennsylvania, March 18, 1884.)

The Author refers to a "Treatise on the Decrease of Water in Springs, Creeks, and Rivers, contemporaneously with an Increase in Height of Floods in Cultivated Countries," by Gustav Ritter von Wex, Chief-Engineer of the Improvement of the Danube at Vienna, translated by General Godfrey Weitzel, of the Corps of

Engineers, United States Army, and a large portion of the Paper is taken up with a criticism of von Wex's views.

A larger extent of country has been disforested during the last forty years in North America than during a century and a half in Europe. In the Allegheny valley several billion feet of timber have been cut, and a much larger quantity of timber has been recklessly destroyed by forest fires and by the process of girdling trees in opening up farms. Rain-gauge records, however, from thirty-seven places show that the annual rainfall during the years 1876–80 has been 1·68 inch more than during the years 1871–75. The record from Philadelphia for sixty-four years shows an increase in the rainfall, and that from Cannonsburg and Pittsburg for forty-five years indicates the same thing.

There are remarkable variations in different parts of the United States in the amount of snow and rainfall, and in the proportion evaporated. The great Missouri valley, fully twice the area of the Ohio basin, discharges, according to Humphreys and Abbott, only 3·7 trillion cubic feet per annum, as compared with 5 trillions by the Ohio into the Mississippi. Yet Professor Cyrus Thomas, and many others, are of opinion that with the advancement of settlement and cultivation in this region the moisture increases. Agricultural operations are being conducted on the great plain of the Columbia river and elsewhere in the West without the aid of irrigation, where a few years ago nothing would grow without artificial aid.

At Pittsburg the flood of 1884 (the highest on record) was only 4 inches higher than that of 1832. Between the years 1851-67 inclusive (omitting two years of which there is no record) there were eight floods reaching 25 feet or over, five of which were over the 30 feet mark. The mean high water for the sixteen years was 24·7 feet. Between 1868–84 inclusive there were only four floods reaching 25 feet, and not until the recent great flood did the river rise to 30 feet. The high water mean for the period is 23·6 feet. The low water from 1855 to date, when divided into two equal periods, was the same for both, viz., 8 inches.

The Author considers that there is nothing in the river records of Pittsburg on which to establish any theory either for increase in height of floods, or for less low-water discharge, due to the destruction of forests or any other cause.

The records of the Monongahela Slackwater Navigation Company, since 1841, do not indicate a tendency towards a decline year by year in the low-water discharge.

The river-record of Cincinnati extends only from 1858 to 1884. From 1858 to 1870 inclusive five floods exceeded 55 feet in height, the highest being in 1862, when the water reached 57 feet 4 inches. Mean for the period, 49 feet 11 inches. From 1871 to 1883 inclusive, only three floods exceeded 55 feet (or four with the 1884 flood included). The mean high-water was 49·9 feet, or, including the late flood, the mean would be 51 feet 3 inches. Two such phenomenally high floods in two successive years seriously affect-the average. The mean annual and low-water levels are slightly lower in the second than in the first period, the low water being 2 inches less.

In conclusion, the Author expresses his conviction that, though the popular opinion is that the destruction of forests increases the height of floods, this belief is not founded on established facts.

The Paper is accompanied by diagrams and Tables of river-levels, rainfall, &c.

In the discussion upon the Paper, the general opinion seemed to be that the destruction of forests had very little, if any, effect upon the river floods.

W. H. T.

The Water-Supply of Philadelphia.[1]

(Annual Report of the Chief Engineer of the Philadelphia Water Department for the Year 1883. Philadelphia, 1884.)

The Philadelphia water-supply has been since 1854 in the hands of the city. The principal source of supply is the Schuylkill river, water from which is raised at seven pumping stations into nine reservoirs having a total capacity of 191,224,560 gallons. The population served amounts (census of 1880) to 847,542, and the average daily pumping being in round numbers 69,000,000 of gallons, the supply per head is about 81 gallons. The receipts for 1883 were $1,627,069, and the expenditure $1,047,227, showing a gross profit to the city of $579,842. A general re-inspection of the city, effected in 1883–84, is expected largely to increase the receipts for 1884. Complaint is made of the universal waste of water by the consumers. Horse-troughs, water-closets and sink-taps are purposely left running, under the impression that a constant flow through the drain is necessary for health. In one case it was discovered that a mill which had been shut down at three o'clock on Saturday afternoon wasted the full stream from a 4-inch pipe until work was resumed on Monday morning. This waste probably amounted to 500,000 gallons in twenty-four hours, enough to supply from twenty to thirty families for a whole year. A hydrant in the yard or a horse-trough will waste about 6,000 gallons daily. Another considerable source of waste is the indiscriminate and unlawful use of the fire-plugs, which are used for all purposes, without reference to the inscription on each instrument, which imposes a fine of $5 for this offence. If the waste could be stopped, the annual expenditure of the department for coal alone might be reduced from $130,000, the present figure, to $80,000. On the other hand, the saving of water would effect a general increase of pressure, and enable the water to reach the upper stories of houses to which it is now a total stranger.

Comparing the total number of buildings with the total revenues of the department, it may be said generally that the average charge per building is $10 per annum. At the rate of charge for water by meter, viz., 60 cents per 1,000 cubic feet or 8 cents per 1,000 gallons, a house paying $10 per annum is entitled to, say 17,000 gallons; or if it pays $15, to 25,000 gallons, amounts much in excess of those actually drawn. For the prevention of waste, the remedial measures may be classed under several heads, viz., instrumental determination, domiciliary inspection, regulation of plumbing appliances, and infliction of suitable penalties. These may all be employed conjointly. In private houses the Bell "Waterphone," or some similar instrument, has shown itself of use; but if the Water-Department is to maintain a perpetual conflict with defective appliances, a considerable increase of force will be required. In this direction legislation is needed, both to restrict waste and to protect the public health.

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[1] The original is in the Library of the Inst. C.E.

The report, of nearly four hundred pages plentifully illustrated, is full of interesting information, and seems to constitute a far more elaborate and complete document than is issued by any Water-Department in the United Kingdom.

F. G. D.

The Sewage-depositing Tanks of Frankfort-on-the-Main.

By W. H. Lindley, M. Inst. C.E.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xvi., 1884, p. 545.)

These works are now in hand, and will be completed in the early part of 1886. The sewerage-works, comprising a network of about 160,000 metres of sewers, have been in execution since the year 1867, and are for the greater part complete. The subsidence-tanks form the completion of the outfall section of these works, and by the plan adopted two outfalls were needed, one on the right, the other on the left bank of the river, discharging into the river main at some distance below the town. While the more costly outfalls were in progress, a temporary outlet was made use of at the gasworks, and this now serves as a storm-overflow. At first the admission of the water-closets was left an open question, as the sewers were constructed to attain a number of important results which could not be delayed till this question, then so largely debated on the Continent, was settled. Professor Pettenkofer, at that time opposed to the water-closet system, however, when called in, reported in this case in its favour, and the prohibition was withdrawn. Owing to the rapid discharging power of the town sewers, the excrementitious matters and paper came down in considerable quantities in a very unchanged condition into the river, and occasioned nuisance, and steps had to be devised to screen out the grosser suspended matters from the sewage water.

After many difficulties, caused by the landed proprietors, and after much pressure had been brought to bear upon the municipal authorities, plans for dealing with the sewage water were prepared so far back as 1876–77, but for various reasons the matter remained in abeyance. In fact, though constant negotiations were in progress, it was not until October 1882 that the scheme was finally settled. It was decided to bring all the sewage-water to the left bank for treatment, and to effect this the sewage is carried in two wrought-iron pipes, each 0·75 metre (2·46 feet) in diameter, laid as an inverted siphon under the bed of the river. Each of these pipes can deliver 500 litres (110 gallons) of sewage per second. The extra pipe is added to provide for subsequent increase of population, as the one pipe will suffice for the whole of the present flow, including a rainfall equivalent to the sewage in volume. For heavy rainfall, which might exceed the carrying-capacity of the siphon, a storm overflow is provided. The main outfall sewer is capable of discharging 2,700 litres (594·2 gallons) per second, but it was considered unnecessary to arrange for bringing all this volume across the river, as it would not have been feasible to construct tanks for so large a volume of rain-water, and it would have simply been turned into the river as storm-water. For the normal volume of sewage, the one pipe only is employed, the area of cross-section normally in use is thus reduced to one-half what it would have been if one pipe of equivalent carrying power to the two laid had been adopted; the normal velocities have thus been about doubled, and this will, it is expected, be sufficient to scour out the siphon. Plans are given, showing the arrangement of the tanks and works. The process to be employed will comprise a system of mechanical purification, aided by chemical purification. It is thought expedient to remove first from the sewage such substances as can be separated by simply mechanical appliances. These impurities consist of floating bodies, coarser suspended matters, and the heavier substances which sink to the bottom. The precipitants to be subsequently employed are sulphate of alumina, and lime. As is well known, the acid in the former substance combines with the alkaline matters in the sewage, and sets free the alumina, as a bulky flocculent precipitate, which, by its affinity for organic substances, entangles them and carries them down. As sufficient alkalies are not present in the sewage to liberate the whole of the alumina, a certain proportion of lime has to be added. The advantages of this treatment are set forth. The plan of tanks adopted will not be carried out at present in its entirety, but will provide for future extensions. The whole scheme comprises twelve parallel tanks, of which only four are now in progress of execution.

The chief point to be considered in respect to the construction of the covered tanks was whether they should be above ground or sunk, *i.e.* high-level or low-level. The former plan would involve continuous pumping to a height of from 5 to 6 metres. By adopting the alternative arrangement of low-level reservoirs, it is possible, without any pumping, to pass the sewage into them by gravitation, and to discharge the clarified effluent into the river on an average of three hundred days in the year. Only on forty-seven days in each year does the river rise to such a level as to involve partial pumping of the contents; and only on about one day in three years is the river so much in flood as to render the use of storm overflows necessary for the whole of the sewage. The extra cost of sunk tanks would be compensated for by the avoidance of pumping. The machinery for pumping and treating the sludge, which is the part of the process presenting the most difficulty, has been concentrated at the lower end of the tanks to which the sludge naturally gravitates. The dimension and inclination of the main outfall-sewers, the arrangement of the sand-intercepting chambers, the bye-passes, overflows and storm-outlets, the mode of admitting the water into the tanks, of passing off the clarified effluent, draining the sludge of a maximum amount of its water, and finally drawing off the sludge, are fully described. The four tanks are each 82·4 metres (270·3 feet) long × 6·0 metres (19·68 feet) broad. The bottom is formed of an inverted brick arch, and falls 1 metre in the direction of its length; the depth of the water in the tanks being 2 metres at the inlet and 3 metres at the outlet end. Each tank has a normal capacity of 1,100 cubic metres (242,106·7 gallons), and is calculated to receive from 4,000 to 5,000 cubic metres daily, under average conditions of flow. The contents are thus about 25 per cent. of the whole quantity to be treated; the corresponding proportions at the following English towns, by which the Author was guided, being—Leeds, 22½ per cent.; Coventry, 30 per cent.; Aylesbury, 26 per cent.; and Burnley, 16 per cent. The total average daily volume of sewage water to be treated at the present time amounts to 18,000 cubic metres (about 3,961,746 gallons). The average velocity of the sewage-water in passing through the tanks is 4 millimetres per second (about 0·786 foot per minute). It is intended to empty each tank weekly. Full particulars are given concerning the machinery for pumping and preparing the precipitants, the stores (which will contain 200 tons of sulphate of alumina and 180 tons of lime), as also the proposed plan of dealing with the sludge and detritus, and the general method of carrying on the works. G. R. R.

The Röckner-Roth Process for the Purification of Sewage- and Waste-Waters from Factories.

(Gesundheits-Ingenieur, September 30, 1884, p. 569.)

This process, which has been in operation in Dortmund, furnishes a ready means for the purification of manufacturing waste liquids. It is both mechanical and chemical in its action. The chemicals employed vary in accordance with the composition of the water to be dealt with, but it is claimed that the utilization of these compounds is so complete that a relatively small quantity suffices, entailing only a moderate cost. After the addition of the chemicals a separation from the liquid takes place of the suspended and dissolved impurities and the matters resulting from the chemical reaction. The subsequent mechanical treatment consists in the introduction of the mixture into a simple apparatus, in the form of an upright cylinder about 7 metres (22·96 feet) high, whose diameter is regulated by the volume of liquid to be treated in a given time. This vessel has certain pipes connecting it with a small air-pump, the dimensions of which for the treatment of 200 cubic metres (44,000 gallons) per diem were as follows: cylinder, 75 millimetres (2·95 inches) in diameter; stroke, 210 millimetres (8·26 inches). It was found practicable in 8 minutes with this pump to exhaust the air entering the receiver in the course of 5 hours; so that a similar pump, used continuously, would suffice for the daily purification of upwards of 7,000 cubic metres of sewage. Owing to the vacuum produced in the receiver, the external atmospheric pressure slowly forces up the sewage water, together with the precipitate, and this mixture undergoes complete separation of the liquids from the solids. Then by a siphon-like contrivance which is entirely self-acting and continuous in its operation, the purified liquid is caused eventually to flow away at the top of the vessel. Arrangements are made for the escape of oil and the specifically lighter matters at the upper part of the siphon.

By the action of the apparatus, the necessary slow upward movement of the liquid is effected, and by this means also the specifically heavier, suspended matters, and the precipitate resulting from the chemical treatment are deposited at the bottom. Layers of sludge are thus formed in the lower part of the receiver and in the basin beneath it, from which latter the deposited matters may, either continuously, or from time to time, be withdrawn, mingled with a small proportion of the liquid. The presence of this layer of sludge is of much importance, as it acts as a species of filter for the subsequent volumes of sewage, and avoids the waste of chemicals, which in former cases, and under ordinary methods of precipitation at once fall to the bottom of the tank and no longer act on the liquid under treatment. The following are among the advantages of the process set forth by Dr. Kaysser of Dortmund. Absolute separation of the suspended, and to a great extent also of the dissolved mineral impurities, and the production of a clear, colourless effluent, free from smell. The removal from the water also of the gaseous admixtures, thereby rendering it incapable of supporting the life of the lower organisms; the water remaining slightly alkaline after the treatment, no free sulphuretted hydrogen can be present. The sludge contains all the matters of use to the agriculturist, in the form of a dense and readily utilizable mud; and moreover the purification is effected in an enclosed space, and can therefore give rise to no pestilential effluvium.

G. R. R.

Intermittent Flushing for Urinals and Water-Closets.

By F. Cuntz.

(Gesundheits-Ingenieur, 15th Aug., 1884 p. 481.)

After referring to the large quantity of water needed for the flushing of the public urinals of Karlsbad, on the constant system, which formerly amounted to 4 cubic metres (880 gallons) per place per diem, or, for the fifty-six urinal-places, 224 cubic metres of water, being over 10 per cent. of the total daily average consumption of the town, five hundred out of seven hundred houses of which have water laid on, the Author states that it became necessary to adopt some other system, and the plan he has introduced, with complete success, is described by reference to a diagram. Two flushing cisterns are placed one above the other; the upper one is furnished with a siphon made of pipe 13 millimetres (0·51 inch) in diameter; the lower cistern has a siphon 25 millimetres (0·98 inch) in diameter, which can only be brought into action by a large flow of water. The smaller siphon will work with a flow of only ½ litre of water per minute. When the upper flush-tank discharges itself it partly fills the lower tank, which has a capacity of 7 litres (1·54 gallon). The upper tank again fills, and at the second discharge fills and starts off the lower tank, which empties itself very rapidly, producing a powerful flush and utilizing the joint contents of the two cisterns, namely 12 litres (2·64 gallons) of water. The employment of this apparatus not only causes a saving of 80 per cent. of water, but also does the flushing much more effectually than the former continuous supply at the rate of about 3 litres (0·66 gallon) per place per minute. It is found in practice that one flush every five minutes is ample, involving a daily use of 3½ cubic metres (770 gallons) of water for a stand of six urinals, as against 24 cubic metres (5,282 gallons) for the same set of urinals on the former system.

The same apparatus can be used with excellent effect for closets, and details are given of the use of this contrivance in a large school. For eighteen closets and nine urinals, used by four hundred and ninety-seven children, 8·820 cubic metres (1,941 gallons) of water, or 18 litres (3·96 gallons) per child per diem was all that was required. By means of a tap the apparatus was instantly started and stopped, before and after school hours.

G. R. R.

Draft of the Main Conditions and Formulas for Calculating the Thickness of Plates for New Boilers.

(Zeitschrift des Vereines deutscher Ingenieure, No. 36, 1884.)

At the meeting at Brussels on 6th and 7th July, 1884, of the delegates and engineers of the Union of Associations for the

Supervision of Steam-boilers, the following sketch of the main conditions and formulas for calculating the strength of steam-boilers was received, and it was decided to publish the sketch, together with tables worked out from it, so that if shortcomings were found in them, suggestions for their improvement might be made.

1. In calculating the strength of a new boiler a factor of safety of at least five is to be taken at the weakest place, taking into account the riveted joints. The strength of the joint is to be calculated by the formulas

$$z = \frac{e - d}{e} \cdot 100$$

$$z_1 = \frac{f . n . x}{e . \delta} \cdot 100.$$

where δ = thickness of the metal in millimetres.
d = diameter of rivet-hole ,,
e = pitch of rivets ,,
n = number of rows of rivets.
z = percentage which the strength of the plate in the joint is of the full strength of the plate.
z_1 = percentage which the strength of the rivets in the joint is of the strength of the full plate.
x = 1 in the case of lap-joints and single-covered joints.
x = 1·75 in the case of double-covered joints.
f = area of rivet in square millimetres (after riveting).

2. On practical grounds, especially in view of the practicability of caulking, and of the manner of fixing of the boiler, the curved plates of the outer shell should not be less than 7 millimetres ($\frac{11}{40}$ inch) in thickness.

3. The conditions laid down by the Union of Associations for the Supervision of Steam-boilers, for the testing of materials for boiler-construction ("Würzburg Rules"), are to be the limits of least strength of the boiler plates.

4. The riveted joints must always be so arranged that the resistance of the rivets against shearing is at least equal to the strength of the plate in the line of the rivets.

5. For the strength of plane surfaces, end-plates, &c., a formula cannot be given, because the staying is here the chief thing, and also because in large marine boilers the end-plates have to be made of plates of various thicknesses.

6. About bracing no detailed regulations are to be made, in order not to hamper the builder unnecessarily.

7. If a vacuum occasionally occurs in the boiler, it must be made at least strong enough to withstand safely an outside pressure of 1 atmosphere.

8. The formula for calculating the strength of the shell must

admit of taking into consideration the absolute strength of the material to be used.

9. With a view to durability the formula for the strength of the shell-plates must contain a constant whose value must be in accordance with the local influences. For plates exposed to flame a further addition is recommended.

10. This constant varies from 0 to 3 millimetres.

11. Plain flues must have sufficient resistance to external pressure without depending on any stiffenings. Stiffenings are to be considered only as constants of extra security.

The following formulas are based upon these principles—

For shell-plates $\delta = \frac{2500\,D\,.\,p}{K\,.\,z} + c,$

and for plain flue-plates $\delta = 1{\cdot}8\,D\,.\,p + 4$ millimetres.

where δ = thickness of plate in millimetre.
D = diameter in metres.
p = pressure in atmospheres.
K = tensile strength of the material in kilograms per square millimetres.
z = percentage of strength of plate in longitudinal joint.
c = constant ranging from 0 to 3 millimetres.

In accordance with 4, the following formulas for riveting are proposed—

$$d = \frac{45\,\delta}{15 + \delta}$$

for single riveting $e = \frac{300\,d}{106 + d}$

for double riveting $e_1 = \frac{500\,d}{132 + d}$

where d = diameter of rivet-hole in millimetres.
δ = thickness of plate „
e and e_1 = pitch of rivets „

Various tables embodying these results are to be obtained from the chief engineer of the North German Association for the Supervision of Steam-Boilers, Hamburg.

W. B. W.

Rules for Conducting Boiler-Tests. By William Kent.

(Transactions of the American Society of Mechanical Engineers, vol. v., 1884, p. 260.

Owing to the want of uniformity that exists among the methods adopted by engineers in making boiler-tests, it is proposed that a standard system should be fixed upon, and the following results always reported:—

1.	Heating-surface	Sq. ft.
2.	Grate-surface (feet inches long by feet inches wide)	Sq. ft.
3.	Ratio of heating- to grate-surface.	
4.	Kind of fuel used.	
5.	Duration of test.	
6.	Average steam-pressure	lbs.
7.	,, temperature of feed	deg.
8.	Lbs. of coal burned	lbs.
9.	,, refuse	,,
10.	,, combustible	,,
11.	Per cent. of refuse	per cent.
12.	Coal burned per square foot of grate per hour	lbs.
13.	Total water evaporated	,,
14.	Water evaporated per hour	,,
15.	,, ,, per square foot of heating surface per hour	,,
16.	,, ,, per lb. of coal, actual conditions	,,
17.	,, ,, ,, combustible, actual conditions	,,
18.	,, ,, ,, of coal from and at 212°	,,
19.	,, ,, ,, combustible from and at 212°	,,
20.	Quality of steam (moisture or superheating).	
21.	Rated HP. (builder's rating)	HP.
22.	HP. developed at 30 lbs. of water evaporated per hour from and at 212°	,,
23.	Per cent. above (or below) rated capacity	per cent.
24.	Temperature of boiler-room	deg.
25.	,, flue-gases	,,
26.	Force of draught in inches of water	inches.

A code of rules is then given for guidance in the examination of the boiler, piping, and valves, before and after the trial, and also for the measurements of fuel, feed, and priming water.

The following four methods of starting and stopping a test are considered:—

1. Starting with the fires in full working order, and stopping with the fires in the same condition.

2. Entirely removing the fuel just before the start, and making fresh fires with weighed fuel, and weighing all left at the end of the trial.

3. Starting when the fires are low, and before the doors are opened for cleaning; then rapidly cleaning the grates, making up fresh fires with weighed fuel, and finishing the trial when the fires are burnt as low as they were at the commencement.

4. Starting and finishing in each case after the fires are cleaned, taking care that the same amount of fuel is left on the grate after each cleaning.

The Author is of opinion that the last method is the best, and fully recognizes the fact that an error of uncertain quantity exists in the estimation of the conditions of the fires at the commencement and end of a trial, but it will be less on the fourth method than on the first, and also be smaller than the error against the boiler due to cleaning grates and getting up fresh fires, as in the second and third methods.

No test ought to endure less than twenty-four hours, and the longer it is the smaller will be the percentage of error.

The coal should be weighed and delivered to the stokers, say every hour, and all other data so taken that the trial may be divided up, and the degrees of uniformity in the results ascertained.

At least ten calorimetric tests of the dryness of the steam should be made during the trial, with thermometers accurate to $\frac{1}{10}$ of a degree, and with a weighing machine correct to $\frac{1}{100}$ of a lb.

J. G. M.

On the Means for the Prevention of Incrustation in Boilers, and the Purification of Locomotive Feed-water. By — BERGK.

(Der Civilingenieur, 1884, p. 449.)

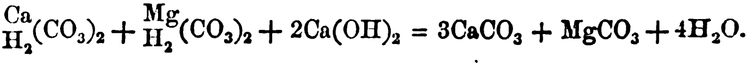
The means for the prevention and lessening of deposits in boilers may be classed as follows:—

1. Washing or rinsing the boiler with powerful jets of water.
2. Removal of the substances producing incrustation by mechanical appliances.
3. Preventives added to the water.
4. Purification of the water in special tanks, by means of chloride of barium, soda and lime, and caustic soda and lime; which to a great extent remove the cause of incrustation.

The Author describes at length the special advantages of the above means, and gives a review of the chief apparatus employed for freeing the water of substances producing incrustation.

Purification of the Feed-water by Chemical operation.—Carbonate of lime, carbonate of magnesia, and sulphate of lime are the main substances found in solution in water, which are answerable for the incrustation in boilers. The first two of these substances do not in themselves occur to any great extent in solution; but are kept in that state in the shape of carbonates by the presence of carbonic acid. If the carbonic acid be extracted from the water, the carbonate of lime and carbonate of magnesia are precipitated; this result is attained most readily by heating the water to a temperature of 140° Fahrenheit, and hereon are based the apparatus, by Haswell, Meyer, Friedmann, and others, described in the Paper by the Author. The sulphate of lime is, however, not precipitated by the action of heat; and its effect can only be neutralized by means of chemical agents. For this purpose Stingl uses carbonate of soda, which combines with the sulphate of lime, and forms carbonate of lime and sulphate of soda.

The removal of the carbonate of lime and carbonate of magnesia is effected by the use of lime instead of heat. The process is shown by the following formula:—



$$\substack{\mathrm{Ca} \\ \mathrm{H_2}}(\mathrm{CO_3})_2 + \substack{\mathrm{Mg} \\ \mathrm{H_2}}(\mathrm{CO_3})_2 + 2\mathrm{Ca(OH)_2} = 3\mathrm{CaCO_3} + \mathrm{MgCO_3} + 4\mathrm{H_2O}.$$

Lime has been used before for this purpose, but the form in which it is applied in the Berenger-Stingl process is new, and has always been attended with very satisfactory results. The difference in the application consists in the employment of a solution of quicklime instead of slacked lime.

The process of converting the substances held in suspension in the impure water is effected by mixing the water with the chemical agents, in the proportion of 10 to 1. To this end a solution of quick lime and caustic soda is made to flow from two tanks, situated above the actual clearing apparatus, simultaneously with the water to be purified, in the proportion of 1 to 10, into a vertical pipe 6 inches in diameter, from which it enters a conical cup attached to the floor of a cylindrical vessel, by which means a disturbance of the matter already precipitated in the latter is prevented. As soon as the cylindrical tank is filled, the water overflows into a second, then into a third, and finally into a fourth tank; all of similar construction, but increasing in height and in diameter, from 2·4 to 5·6 feet. The total capacity of the tanks is 31 cubic yards, which amounts to two and a half times the volume of water to be purified per hour. The water remains in the filtering-tanks for five and a half hours, and during that time travels a distance of 66 yards.

The water required at the Bavarian Station in Leipzig for feeding the engines amounts to 143 cubic yards per diem; this is for the greater part obtained from springs, only a small quantity being supplied by the town waterworks. According to an analysis made by Dr. Fleck, the water contains the following substances:—

	Gram.
Sulphate of lime	0·0843
Carbonate of lime	0·0726
Carbonate of magnesia	0·0352
Nitrate of magnesia	0·0053
Chloride of sodium	0·0252
Silicate of soda	0·0285
Carbonate of ammonia	0·0003
Organic substances	0·0043
Total	0·2557 gram[1] in 1 litre of water.

The hardness of the water varies from 18·3° to 23°, and after purification from 3·5° to 4°.[2]

J. R. B.

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[1] 1 gram per litre = 70·105 grains per gallon.

[2] The degree of hardness is determined by the number of milligrams of lime contained in 100 cubic centimetres of water.

The Pumping-Arrangements of the Bockwa Coal-Mines Union.

By C. Wagner.

(Jahrbuch für den Berg- und Hüttenmann (Freiberg), 1884, p. 156.)

The Bockwa district of the Zwickau coalfield includes within an area of about 450 acres upon the southern limb of the basin, the outcrops of three of the principal seams. These have been worked from the surface downwards, and as there is but little cover, and that mostly of a permeable nature (sands and gravels), the mines are subject to a considerable influx of water. The ownership of the ground being very much divided, and the extent of the individual mines small, it became necessary to form a union in order to provide suitable pumping arrangements. This was done in the year 1851, when the works described by the Author were commenced.

Originally, a principal source of danger to the mines was a brook called the Schmelzbach, crossing the district about midway from south to north, which swelled very rapidly in heavy rains, besides letting large quantities of water through the gravel, forming its bed. This has now been obviated by turning the course of the brook, which is led by an artificial channel into a district, for the most part, lying outside of the coal measures—a work that was carried out in 1864. The largest and most important feeders, however, are those derived from the gravel bed of the Mulde river, which runs along the western side of the district, and these cannot be stopped out artificially.

The district is approximately rectangular, the strike of the coal seams following the breadth from east to west, about ¾ of a mile, while their dip is from south to north. The first work undertaken in 1853 was the placing of a pumping-engine at the lowest northern point of the district in a shaft (No. I.), which was sunk to 181 metres, with a series of levels connecting it with the different mines at the bottom, as well as at the depth of 138 metres. This shaft, rectangular in section, 6·2 metres by 2·5 metres, was originally divided into four parts, a principal compartment for pumps, two drawing shafts, and a footway; but this has been subsequently modified, the second drawing-shaft being suppressed in order to make room for a new column of pumps. For a depth of 53 metres from the surface the shaft is secured by stone and brick masonry, but below that rectangular timber framing is used. The first engine erected in 1855 is a single-acting Cornish engine of 200 HP., 1,990 millimetres piston diameter, and 3,140 millimetres stroke with an unequal armed beam, in the proportion of 5 : 4, giving a stroke of 2,510 millimetres in the pumps, which are 570 millimetres in diameter. The total head of 181 metres is divided into four lifts. A noticeable peculiarity is in the arrangement of the bottom drawing lift, which is of the same diameter as the plunger-lifts above, and delivers the water directly into the valve-box of the latter without the use of intermediate cisterns or suction-pipes. This arrangement is of course conditioned by the fact that the whole of the water is lifted from the bottom of the shaft. The main-rod is forked at the point of attachment of the plungers, which are connected by cross-heads and side-rods, so that their line of effort is central with that of the rod. As originally built the main-rod was of pine wood, but after 28 years' service, the upper part down to the second plunger lift, a length of 133·5 metres, was replaced by an iron rod of box section, built up of plates and U-bars. This is of smaller dimensions than the old rod and considerably lighter, weighing only 35 as against 52 tons, which has led to a considerable economy in steam-consumption.

Five years after the erection of the first engine, the increased area of the workings had led to so great an increase in the water-supply, as to render a second or auxiliary engine necessary, which was erected in one of the drawing compartments of the No. I. shaft. This like the first was supplied by F. Wöhlert of Berlin, but is of a different character, the direct-acting Bull form being adopted, with the cylinder carried upon wrought-iron girders above the shaft. It is of 150 HP., 1,570 millimetres piston-diameter, and 2,825 millimetres stroke. The lifts in the shaft are similar to those of No. I., but of the smaller diameter of 425 millimetres.

In 1872 it became necessary in the interest of the safety of the workings to provide further pumping-power, and as the entire area of the first shaft was now occupied, a second shaft was decided upon. This has been placed on the western side of the district adjoining the safety barrier of unwrought coal left, for the support of the Mulde bed, 640 metres to the south-west of No. I. shaft, and 380 metres to the rise of the measures. It is of rectangular section, 6·40 × 2·30 metres, and otherwise generally similar to No. I., although being for the most part in strong sandstone, only 8 metres of brick walling were necessary, the remainder being timbered. The depth is 104 metres. The lifting power originally provided is a direct-acting engine of 150 HP., by the same makers, and similar to the reserve-engine of No. I. shaft, working plunger-lifts of 470 millimetres diameter. This was supplemented in 1882 by a direct-acting rotary engine of 130 HP., built by Hoffmann and Zinkeisen of Zwickau. This is placed underground in a chamber cut out of the sandstone rock, whose length is perpendicular to the western long side of the shaft. The engine-room is 17 metres long, 4·35 metres high to the crown of the brick arch, and 4 metres in greatest breadth. The steam-cylinder is 950 millimetres in diameter, and the pump-plungers 330 millimetres, both having a common stroke of 950 millimetres. Steam is supplied from the surface by a pipe 130 metres long, covered with a layer of non-conducting composition 3 metres thick; the loss of pressure being at most ⅖ of an atmosphere, the amount of steam condensed has not, however, been determined. The rising-main of the pump is 375 millimetres in diameter, the suction lift is 2·75 metres, and the forcing lift 104 metres. The water from the suction-pipe passes through the surface-condenser in order to furnish the necessary vacuum. When making 25 revolutions the amount of water lifted is 3·75 cubic metres per minute.

The drainage of the district is effected by a series of collecting drifts, following the strike of the strata, and generally parallel to each other 200 to 280 metres apart horizontally, which are connected by dip headings leading to the sumps of the engine shafts. The total length of these drifts up to the present time is 7,900 metres (nearly 5 miles), of which length 5,600 metres are driven in the coal-seams, and 2,300 metres as cross-cuts.

The lifting-power of the three surface engines is 6·86 cubic metres when making 4½ to 5 strokes per minute, which, in addition to that of the underground engine, 3·75 to 4 cubic metres, gives a total of 10·5 to 11 cubic metres. The average amount lifted during the year 1882 was 3·94 cubic metres or 173·5 cubic feet, which, however, was very unequally distributed, being only 2·72 cubic metres in dry weather at the beginning of the year, and increasing to 10·50 cubic metres during the long continued rains in the later months.

H. B.

Some further Notes on the Useful Effect of Pumping-Engines in the Zuid Plaspolder. By P. A. KOREVAER.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1884, p. 217.)

Mr. Exalto criticised some conclusions as to the respective merits of the scoop-wheel and the centrifugal pump, based on the consumption of coal by either system.[1] The Author avers that the advantages in this respect of the centrifugal pump are only apparent, and that at all events for waterlifts not exceeding 6 feet scoop-wheels are decidedly cheapest with regard to working expenses. This opinion is derived from numerous examples and observations.

H. S.

Power-Regenerator for Pumping-Engines. By H. LUEG.

(Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, vol. xxxii., 1884, p. 260.)

In 1869 the then Inspector-General of the Austrian State Railway, Mr. August Bochkoltz, patented, under the name of Power-Regenerator, a contrivance for utilizing the work developed by the unbalanced load of the main rods of deep-mine pumping-engines, by the addition of an air-compressor, the power in excess of that required for opening the pump-valves given out when at the maximum of speed being stored up in the compressed air, which becomes auxiliary to the steam at the next change of stroke. Several memoirs on the application of the invention were published, the more important of which will be found in the "Zeitschrift des Vereines deutscher Ingenieure" for the year 1873. The invention does not appear to have attracted much attention for several years, but in 1878 it was taken up by Messrs. Haniel and Lueg, of Dusseldorf, who have applied it in a modified form to several pumping-engines in Belgium and Germany. As originally constructed, the Bochkoltz regenerator consisted of a double-acting piston-compressor placed above the steam-cylinder (in the position of the high-pressure cylinder of an ordinary tandem compound engine), with two air-vessels for storing the compressed air delivered at each stroke, and in this form it was applied in 1878 to a single-acting direct engine at the Clerget pit in Belgium, and, with some alteration in details, to a double-acting engine at Frederick the Great pit at Herne, in Westphalia, in the following year. The difficulty, however, of obtaining a perfectly air-tight piston has led to the substitution of a plunger for the solid piston, and the apparatus so modified has been applied in several instances. The first of these, at the No. III. Dechen pit at Saarbrücken, has been carefully experimented upon, in order to determine the advantages obtainable from its use. The engine is double and indirect-acting, with a steam-piston of 1,177 millimetres diameter, and 3,140 millimetres stroke, working three 600 millimetre plunger-lifts, together of a total height of 197 metres. The regenerator, which is attached to the main-rod in the shaft, consists of two air-vessels placed vertically with a plunger moving through a stuffing-box between them. The amount of compression is regulated by partially filling the air-vessels with water, and a safety-valve prevents the maximum 4·5 to 5 atmospheres (absolute) pressure being exceeded. The effective sections are: of the plunger, 3,870 square cubic metres, and of the steam piston 10,667 cubic metres on the upper, and 10,880 on the lower surface.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiii., p. 433.

The useful working-pressures obtained were:—

1. Without the regenerator	81·4 per cent.
2. With the regenerator	85·5 „

The first of the above figures shows the engine to be a very economical one, which is to be attributed to the high degree of expansion realized, the steam being cut off at from $\frac{3}{8}$ to $\frac{1}{2}$ of the stroke; but even here an increase of 4·1 per cent. in useful effect has been realized, with a corresponding saving of steam. A further advantage is, however, to be found in the greater regularity of movement, whereby an increased working speed can be realized. In order to test this point, experiments were made upon the actual rate of motion of the pump-rods, by means of a specially designed electrical apparatus, constructed by Messrs. Siemens and Halske. This is essentially a Morse seconds-printer, combined with an indicator barrel upon which the motion of the rod describes a curve by means of a screw movement and pencil. The results obtained with the instrument were—

	With Regenerator.	Without Regenerator.	
Duration of up-stroke	2·6	3·2	seconds.
„ down-stroke	2·8	3·4	„
Two cataract pauses	1·6	1·6	„
Total time of double stroke	7·0	8·2	„
Number of strokes	8·57	7·31	per minute.
Maximum velocity of up-stroke	1670	1550	millimetres.
Mean „ „ „	1177	1050	„
Maximum velocity of down-stroke	1650	1500	„
Mean „ „ „	1093	894	„

The diagrams obtained by the indicator show that the increase and diminution of the velocity is practically uniform, the curve being nearly circular when the regenerator is used, while it is decidedly more irregular in contour under the ordinary condition. A series of diagrams, showing great irregularities in speed, are given in the results of experiments upon other engines. The results of the figures given above show that an increase of 17·2 per cent. in the working speed, and consequently of the useful power of the engine, has been realized, apart from the saving of steam of 4·1 per cent. In two other cases an increase of working speed from 5 to 7·5 strokes, and from 5·1 to 8 and 8·5 strokes have been obtained.

Another modification, in which the double-acting regenerator is replaced by two single-acting ones, one at the top and the other at the bottom of the main-rod, has been suggested by the chief-engineer of the Cockerill Company, Mr. Kraft, M. Inst. C.E. Here the construction is simplified, the plunger doing duty as an air-vessel (by the adoption of the telescopic, or bell form), and the dimensions are considerably reduced. A single-acting form designed for use in rotary engines, as a substitute for the heavy load required to give the rod the lead of the crank, which is essential in this form of engine, is also noticed as about to be applied to a pumping-engine of 1,000 HP. This has a plunger of 900 millimetres diameter, and 2,000 millimetres stroke, and is intended to replace an accelerating load of 30 tons now required by the rod.

The Author, in conclusion, sums up the advantages to be gained by the use of the regenerator, and points out that in some cases an increase of useful effect up to 60 per cent. has been realized, while under the most unfavourable conditions the cost of applying it cannot amount to 10 per cent. of the improved value due to the extra work obtained.

H. B.

Experiments on the Humphrey Turbine Water-wheel at the Tremont Mills, Lowell, Mass. By JAMES B. FRANCIS.

(Transactions of the American Society of Civil Engineers, 1884, pp. 295–302.)

The Paper contains an account of experiments to test the efficiency of a Humphrey turbine of 275 HP., constructed to replace a Fourneyron turbine of 162 HP. The fall is 13 feet, and the turbine is an inward- and downward-flow turbine. To test the power of the turbine the ordinary driving gear was removed, and a friction-brake pulley keyed on the shaft. The pulley had water-channels cast in its rim to carry off the heat developed by friction. The brake-strap was connected with a bell-crank supported on knife-edges. A dash-pot controlled the movement of the brake. To get the true head, the water-levels were measured in quiet cisterns connected with the head and tail-race by 1½ inch pipes. The discharge was measured by weirs, in approaching which the water was stilled by gratings. The leakage was independently ascertained, and found to be extremely small. A separate observer noted each datum required, readings being taken every minute. With the regulating-sluice fully open the efficiency was 0·82 per cent., with a circumferential velocity of the wheel equal to 70 or 75 per cent. of the velocity due to the head. As the regulating-gate is closed, the efficiency diminishes, and also the velocity of the wheel giving the greatest efficiency. With the regulating-gate half open the efficiency is 65 per cent., and the best velocity between 57 and 66 per cent. of the velocity due to the head.

W. C. U.

An Underground Guibal-Ventilator at Planitz.

By B. OTTO.

(Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, vol. xxxii., 1884, p. 159.)

At Von Arnim's Colliery at Planitz, near Zwickau, where the ventilation is effected by an ordinary Guibal fan, supplying nearly 3 cubic metres of air per minute for each man employed underground, considerable difficulty has been experienced in keeping the air in certain districts of the workings free from heavy damp (carbonic acid), which is given off in large quantities from the goaves, and mixes with the fresh air in spite of the most careful stopping of the old workings. In order to remedy this defect, the manager of the mine, Mr. Richter, determined upon supplementing the ventilation by a supply of air above the atmospheric pressure, and for this purpose a Guibal fan has been erected to work as a blower, instead of exhausting the air in the usual way, which is intended to move 700 cubic metres per minute, through the workings (about 2500 metres of drifts varying from 2 to 6 square metres in cross section), under ordinary circumstances, with a capacity of increase to 1000 cubic metres by a maximum speed of 100 revolutions per minute.

It is placed near the bottom of the Alexander pumping- and winding-pit, 191 metres below the pit-bank, 5·13 metres above the pit-eye, and 8 metres above the sump—a position which is considered to be sufficiently secure against a sudden rise of water, as there are two engines of 250 HP. employed in pumping. The fan-chamber, 9·5 metres high to the crown of the semicircular roof, is cut out partly in the solid coal of the lower Planitz seam 6 metres thick, and partly in the overlying shales. The side-walls and roof are of hard-burnt brickwork, coated internally with cement brought up to a perfectly smooth face. The breadth of the fan-casing is 1720 millimetres, leaving a clearance space of only 10 millimetres on either side of the blades.

The fan, 7 metres diameter and 1·7 metre broad, has a cast-steel axle of 240 millimetres diameter, carrying octagonal cast-iron seatings for the arms, which are built up of flat iron bars, 130 × 20 millimetres. The depth of the blades is 2200 millimetres. The air is admitted by a circular aperture, 3 metres diameter, on either side of the fan, and passes out by a rectangular drift of 3·38 square metres area, which is connected with the casing by a curved passage. The area of the discharge-passage is regulated by a circular slide in the usual way.

The engine is double-acting, with condenser and variable expansion gear, adjustable by hand. The steam-piston, of 520 millimetres diameter and 800 millimetres stroke, has a speed of 1·2 metre per second when at the normal speed of 45 revolutions, which is increased to 2·66 metres at the maximum of 100 revolutions per minute. The condenser and air-pump are placed on one side of the cylinder, the latter being driven by spur gearing from the outside end of the main shaft. The injection-water is delivered from an upper level under a head of 26·3 metres, so that no cold-water pump is required. Steam is supplied from boilers at the surface by a continuation of a 6-inch pipe, already in use for an underground pumping engine at 183 metres deep, brought in by a drift, 52 yards long, from the pit bottom. The steam-pipe is carried upon rails covered with Klehmet's non-conducting material, and has the necessary copper compensation-joints to allow for changes in temperature.

The engine was started in December, 1881, and has since been almost continuously under steam, with the exception of Sundays and holidays; under ordinary conditions it works with steam of 2 to 2·2 atmospheres (excess) pressure, cutting off at $\frac{1}{10}$ of the stroke with an average vacuum of 700 millimetres.

Numerous experiments have been made to determine the effect realized, of which two examples are given by the Author, as follows:—

March 31st, 1883.—Pressure of water-gauge, 20 millimetres. Temperature, 13·44° C. Mean velocity, 223·165 metres. Discharge, 739 cubic metres per minute.

August 15th, 1883.—Pressure of water-gauge, 19·5 millimetres. Temperature, 21° C. Mean velocity, 3·642 metres per second. Discharge, 723·87 cubic metres per minute.

The entire cost is given at £1348, which is, however, exclusive of boilers, those already in use at the surface being sufficiently powerful to furnish the necessary steam; the separate items being, as follows:—

a. BUILDING WORKS.

	£.	s.
I. Excavation of fan- and engine-houses, engine approach drift-, suction- and delivery-channels	182	18
II. Drift for steam-pipe from shaft, 65·4 metres . .	52	8
III. Cost of masonry—		
Wages of masons and labourers	257	18
Materials (bricks, lime, and cement) . . .	214	2
	707	6
Less amount realized by sale of 1,258½ tons of coal excavated from fan- and engine-rooms .	386	0
Net cost of building works	321	6

b. ENGINE AND MACHINERY.

	£.	s.
Fan- and steam-engine, including iron shutters and erection	684	5
Foundations for steam-engine	53	19
Steam-pipe 57·2 metres cast-iron, 5·2 metres copper	70	13
Covering steam-pipes (wages and materials) .	24	19
Hot-water discharge-pipe 82 metres long . .	72	4
Injection supply-pipe 253 metres long . . .	60	15
Packing material for engine and pipes . . .	2	16
Cost of erecting lines of pipes, lowering engine and machinery down pit, and extra labour in fitting	56	16
	1,026	7
Total cost of buildings and machinery . .	1,347	13

Allowing for interest and sinking fund, 7 per cent. on the buildings and 10 per cent. on the machinery, the annual charge will be £125 2*s.*

The expenditure in wages and materials during three hundred and ten working days in 1882 was £327 3*s.*, or including the sinking-fund charge, about £1 8*s.* 3*d.* per day, corresponding to 0·32*d.* per 1000 cubic metres of air delivered, or 0·61*d.* per ton on the daily output of 550 tons of coal.

The further expenditure upon the establishment and maintenance of the air-ways, crossings, stoppings, and other arrangements incidental to underground ventilation, may be estimated as bringing the cost of 1000 cubic metres of air supplied to about 0·72*d.*—a sum, which is sufficiently large to render the utilization of the air for actual ventilating purposes a matter of considerable importance in the economy of mine-management; for, as pointed out by the Author, there are numerous pits, in which, owing to erroneous mechanical arrangement, not only is the actual working-cost of the ventilator considerably higher, but the air-current induced makes its way by the shortest road to the up-cast shaft, only coming in contact with a minimum of the actual working places.

The effect of this system of ventilation upon the air of the mine has been very decided as regards altering the proportion of carbonic acid present. According to Dr. Hesse, the return-air, as a whole, contained $\frac{11 \cdot 9}{1000}$ of carbonic acid when the exhausting fan alone was used, but that it was diminished to $\frac{8 \cdot 9}{1000}$ when the method of blowing was adopted in addition. The results obtained in individual workings are, however, much more marked. Thus in an end driving by two men in an upper seam, which became inaccessible in fifteen minutes after the stoppage of the fan, the air collected 10 metres away from the face, contained $\frac{27 \cdot 8}{1000}$ of carbonic acid, which was reduced to $\frac{9 \cdot 8}{1000}$ when the fan was at work. The determination was made by a method described by Dr. Hesse in Eulenburg's "Journal of Forensic Medicine and Public Hygiene." New Series. Vol. xxxi. p. 2. The Author concludes by some general remarks on the comparative sanitary effects of pressure and vacuum ventilation.

H. B.

Coal Mining in Upper Bavaria. EMIL HEYROWSKI.

(Wochenschrift des österreichischen Ingenieur- und Architecten Vereines, Oct. 11, 1884.)

The coal-bearing formation of Upper Bavaria belongs to the Tertiary group, and especially to the oligocene (lower miocene) molasse, and runs parallel with the Alps from east to west on their northerly face.

The stratum directly underlying the molasse is the "flysch," which extends from Salzburg to Lake Constance (124 miles). On this "flysch" lies a stratum from 5 to 7½ miles wide of the oligocene marine, and the coal-bearing freshwater molasse.

The coal occurs in ellipsoidal basins, lying lengthwise from east to west. The Hauskam basin is estimated to contain 75,000,000 tons. The workable seams vary in thickness from 6 feet to 1 foot 6 inches, thinner seams not being considered workable. At Miesbach there are three, at Hauskam two, and at Penzberg five workable seams. The coal is dark brown, shelly to splintery, brilliant, fairly hard, durable in dry air, and easily kindled. Its composition is:—

Carbon	50
Hydrogen	4
Oxygen and nitrogen	17
Sulphur	3
Water	10
Ash	16
	100

It reduces to steam four to five times its own weight of water. It is much used for industrial and domestic purposes, but on account of the high percentage of sulphur cannot be used for locomotives. W. B. W.

Coal and Sea-carriage. By Dr. A. Gurlt, Bonn.

(Zeitschrift des Vereines deutscher Ingenieure, Nos. 35, 36, 1884.)

In view of the great increase of production of coal in Germany, especially in Westphalia and the Rhine district, the writer considers its chances of profitable export in competition with English coal. His conclusions are based on experiments conducted by the German naval authorities at the dockyards of Dantzic and Wilhelmshaven from 1862–82. Only twenty-one out of one hundred and ninety-six samples of Westphalian coal were considered fit for use on board ship, and these were tested in comparison with English and Welsh coals with reference to

Hardness and consistency.
Heating power.
Amount of ash.
Amount of smoke.

Hardness and Consistency.—50 kilograms (110 lbs.) of lump coal broken into pieces of about 1 lb. weight each, and screened, were placed in a drum 1 metre in diameter, which was then slowly turned fifty times. The coal was then screened again, the size of the holes being 1·4 square inch (9 square centimetres), and the remaining lumps being weighed gave a measure of the cohesion. The result showed that the best Westphalian coal gave 24·18 per cent. more slack than Newcastle coal, and 21·03 per cent. more than Welsh coal—that is to say, that on a sea voyage under similar circumstances,

52·62 per cent. of Westphalian coal would be broken up small.
28·44 per cent. of Newcastle ,, ,,
31·59 per cent. of Welsh ,, ,,

Heating Power.—1 kilogram of the Westphalian coal converted into steam from 8·898 to 8·333 kilograms of water, while the same weight of Welsh coal converted from 8·569 to 8·142 kilograms, and Newcastle coal 7·298 kilograms, a result in favour of the German coal, but it is to be remembered that this result was obtained on shore, and would not be obtained on board ship owing to the breaking up of the coal in transit.

Amount of Ash.—The Westphalian coal gave from 2·65 to 8·37 per cent. of cinders, ashes, and dust as compared with 8·23 to 10·25 per cent. yielded by the English coal.

Amount of Smoke.—The results of these tests also were slightly in favour of the German coal.

Thus German coal, except for its extreme softness, fulfils the necessary conditions.

On land of course a boiler gets its coal from day to day under almost unaltered conditions, but a ship has to carry its fuel with it, and the coal undergoes in the bunkers a daily though almost imperceptible change, through breaking up and loss of gas, so that in long journeys it loses 25 to 30 per cent. of its heating power. The Peninsular and Oriental Steamship Co. allows its ships about 1 cwt. more coal per sea-mile when they are in Indian, Australian, or East Asian waters than when in European waters, although the average speed in the former is from 1 to 1½ sea-mile per hour less than in the latter.

After describing many methods in use in England for simplifying and facilitating the transport of coal from the mines to ships, the Author urges their adoption in Germany. German coal being softer than English, loses more by rough handling, and requires all the advantages of the English modes of transit; at present it loses by careless treatment no small proportion of its value before it reaches the ship. Once on the ship the breaking up goes on faster than ever, and it has often happened that in the short voyage between Papenburg on the Ems and Dantzic, the best Westphalian lump coal, which at starting had only 10 per cent. of slack, has been so knocked about that on arrival it contained some 60 per cent. With this breaking up other disadvantages are combined, viz., danger of gas explosions and spontaneous combustion, as small coal absorbs oxygen more rapidly than large. When coal has reached a distant port after a long voyage, loss of gas still goes on, increasing with the hotness of the climate, and at a greater rate with soft than with hard coal. It is the experience of the dockyard authorities at Kiel that even in that temperate climate Westphalian loses more gas than Cardiff coal when stacked in the open air. This all shows that Westphalian coal will have to be treated with the greatest care to compete with English coal.

The Author formulates the following conclusions:—

1. As long as the present methods of transport and loading are used, it will be impossible profitably to export German coal by sea.
2. If the English system were followed, it would still be very difficult and risky, because of the extreme softness of the coal, to send it long voyages, but by the exercise of great care it might be profitably exported for short distances.
3. To have a canal for part of the land journey would rather enhance than diminish the difficulties. This has reference to the proposed Ems canal.
4. A more systematic use of the railways which already exist, and those which are to be constructed, is what is required.
5. A profitable result can only be obtained by the expenditure of much capital and ingenuity.

The Author considers that the most profitable way of disposing of the surplus production of the German coal-fields will be found in the manufacture on a larger scale and export of coke and patent fuels.

W. B. W.

On the Waianamatta Shales, Hawkesbury River, N.S.W.

By the Rev. J. C. Tenison-Woods.

(Journal of the Royal Society of New South Wales, vol. xvii., 1883, p. 75.)

The Author disputes the correctness of the views entertained by the late Rev. W. B. Clarke and Mr. Beete Jukes[1] with reference to these shales. These writers held that there was a distinct formation of shale lying on the top of the Hawkesbury sandstone; that it lay in a basin on the eroded surface of the older formations between the Blue Mountains and the sea; and that the shale on the top of such hills as Mount Sugarloaf, Razorback, and others in the neighbourhood of Campbelltown were the outliers, and fragments of what was once a plateau of Waianamatta rock. It is only lately that the true nature of the deposits could be examined. The cuttings and tunnels in connection with the New Waterworks have afforded great advantages for the inspection of the strata. The Author details his reasons for inferring (1) that the shales in question do not lie on the top of the Hawkesbury sandstone, but are intercalated with it; (2) that the shales which lie on the summits of such hills as Sugarloaf, Razorback, Kenny's Hill, cannot be outliers of one elevated plateau, because they are mere seams of shale from the Hawkesbury sandstone; (3) that these shales do not occupy any basin in the formerly eroded rock; (4) that both in the contained fossils and the stratification the shales are one with the Hawkesbury sandstone; consequently (5) there is no such formation as the Waianamatta.

Concluding the geological part of the subject, the Author turns to its economical aspect. Up to this time no great use has been made of the shales, but they are of considerable commercial value. In the manufacture of pottery a certain portion of shale would be equal to any in the world. It consists of true silicate of alumina finely levigated and mixed together with very little iron or other elements. The alumina predominates, and this is to the advantage of the ware. Bricks have been made from the shale from a very early date in the colony, notably at Lithgow, at Waterloo by Messrs. Goodlet and Smith, and at the Oaks Brickworks, at Neutral Bay, and other places. In the latter locality the shale is particularly free from iron and grit, and contains more alumina, so that a very white brick comes from the kiln. It is very tough, and shows a colour and a structure which manifest how easily fine pottery could be made from the same substance; in fact, it seems a pity to use such material for bricks. A high price is paid for firebricks to use with these, in ignorance of the fact that no finer firebricks could be found than that made from the clay itself. The only matter of regret is that near Sydney the supply of the shale is somewhat limited.

F. G. D.

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[1] Journal of the Geological Society, London, vol. iii.-iv. (1847), p. 229.

On the Determination of Arsenic in Iron and Iron Ores.

By E. Lundin.

(Jernkontoret's Annaler, vol. xxxix., 1884, p. 92.)

The nature of the influence of arsenic upon the working properties of iron and steel has never been very exactly determined, it having been variously stated as producing both red- and cold-shortness in malleable iron. The Author, having turned his attention to this question, has devised a method of quantitative determination based upon Poller's process of weighing the arsenic directly as sulphide, described in "Fresenius Zeitschrift," vol. x., p. 41, and Schneider's modification of Almen's plan of distilling the arsenic (as chloride in hydrochloric acid vapour), which is claimed to be simpler and more certain than the methods previously used. The details of its application are as follows:—

1. *For Iron and Steel.*—Six grams of the metal, whether cast or wrought iron or steel, are digested in a beaker of not less than 300 cubic centimetres capacity, with 70 cubic centimetres of nitric acid of specific gravity 1·2, until completely dissolved. The solution is then transferred to a porcelain dish of 150 cubic centimetres capacity; 40 to 45 cubic centimetres of sulphuric acid of specific gravity 1·83 are added, and it is concentrated by evaporation until the nitric acid is entirely driven off. This is best effected upon a sand bath, the heating being continued until sulphuric acid vapours have disappeared, and all bubbling of the mass has ceased. As soon as the latter shows signs of clotting it is heated with a fresh addition of 5 to 10 cubic metres of acid to decompose the last traces of nitrates.

The residual mass is next transferred to a flask of 300 cubic centimetres capacity, 8 to 12 grams of finely-divided ferrous sulphite to reduce the arsenic acid to arsenious acid, and, lastly, 90 cubic centimetres of hydrochloric acid of specific gravity 1·19 are added. The flask is then stopped with an india-rubber plug, having a bent glass delivery-tube, with a pipette of 50 cubic centimetres capacity, attached to it, the point of which is immersed in a beaker containing 300 cubic centimetres of water to a depth of about 12 millimetres below the surface. The flask is then heated over a Bunsen burner, placed about 120 to 144 millimetres below it, when the arsenic distils over as arsenic chloride, and is condensed in the water. The operation is completed when the broad part of the pipette begins to get warm, which usually happens in fifteen or twenty minutes.

The distillate in the beaker is next warmed to 60° or 70° Centigrade, and a current of sulphuretted hydrogen is passed through it until the precipitate of sulphide of arsenic has completely separated, when the solution should be perfectly clear and free from suspended flocks of sulphur. Should these appear, it is likely that the nitric acid has not been completely driven off, in which case some part of the arsenic may remain behind, and the precipitate sulphide, being mixed with sulphur, cannot be weighed, but must be first heated with bisulphide of carbon to remove the latter.

The excess of sulphuretted hydrogen in the liquor is next driven out by passing carbonic acid through it, and the sulphide precipitate, with the assistance of a filter-pump, is collected as rapidly as possible upon a tared filter, which is dried at 100° to 110° and weighed. It contains 60·98 per cent. of arsenic.

2. *For Iron Ores.*—Four grams of the ore, very finely powdered, are digested at a moderate heat with 40 cubic centimetres of nitric acid of 1·4 specific gravity for nearly twelve hours, and subsequently for a further similar period with acid of 1·19 specific gravity, nearly to dryness. Sulphuric acid of 1·83 specific gravity is then added, and the operation is continued exactly as described for metallic iron. An excess of nitric acid is essential during the solution of the ore to prevent loss of arsenic by volatilization.

The consideration of the influence of arsenic on iron led to the investigation of the following inquiries by the Author:—

1. Is arsenic a cause of red-shortness, and to what extent must it be present to be appreciable?
2. Can Eggertz's sulphur tests by a polished silver plate be relied upon with arsenical iron or steel?
3. Can red-shortness in iron at high temperatures (bright red heat) be caused by arsenic?

The reason for these inquiries is to be found in the circumstance that the Author was for a long time engaged in smelting ores containing arsenic, which gave an iron that showed 0·03 per cent. of sulphur at most by the silver-plate test, but was in the highest degree red-short under the forge test, though at a higher temperature than that at which red-shortness ordinarily appears. The discrepancy between the two tests may be explained by the circumstance that sulphide of arsenic is not soluble in weak acids; so, supposing the two metalloids to be present, a portion of the sulphur present may be kept back in combination, and therefore show too low a result by the silver-plate method. The following analyses have been made in the Author's laboratory in illustration of the questions raised above:—

	Arsenic. Per cent.	Sulphur. Per cent.	
		By Silver Plate.	By Precipitation with Ba Cl.
Pig iron	0·07	0·03	0·055
„	0·03	0·03	0·035
Bar iron No. I.	0·09	0·03	0·092
„ No. II.	0·015	0·015	0·022

The first of the samples of bar iron was exceedingly red-short, while the second was in every way satisfactory in quality.

H. B.

A new Form of small Bessemer Plant. By A. TRAPPEN.

(Stahl und Eisen, vol. iv., 1884, p. 524.)

The success of the Bessemer process when carried out on the small scale at Avesta in Sweden, as described by Professor Ehrenwerth, and subsequent experiments of a similar kind made at Prävali, in Carinthia, and elsewhere, have led the Author, who is specially occupied in the building of Bessemer works, to design a plant suitable for operating upon small charges. This consists essentially of a converter about 1 metre outside diameter, and 1·5 metre high, connected by a single trunnion to a horizontal steel shaft carried by the arm of a hydraulic crane, which is very similar in character to the ladle crane of a large-sized converter. The sweep of the crane is such as to allow the converter to be brought close up to the tap-hole of the blast-furnace or cupola, so that the use of open gutters for the fluid metal may be avoided as much as possible. The converter is turned on its axis by a screw and worm-wheel, which is manipulated by a workman standing on a platform at the opposite arm of the crane. The blast is brought in from above by a pipe down the central pillar of the crane which is connected with the blast-main by a flexible tube and packed joint. The outer trunnion bearing is open, so that by slightly raising and lowering the ram of the crane, the converter may be left suspended to a weighing-machine in front of the furnace if it is required to determine the weight of the charge. When the converter is filled, it is borne by the crane into a convenient position for blowing, and if the basic method is followed, for removing the slag, the converted metal is cast into ingot moulds, which are manipulated by a small ingot-crane of the ordinary pattern. In the case of small existing blast-furnaces which usually have their tap-holes near to the ground, it may be necessary to have a shallow ingot-pit (20 to 24 inches deep); but with cupolas this will not generally be necessary, and the whole of the operations may be carried on at the ground level. Each crane is intended to be supplied with two or three converters, so that operations may be carried on continuously. The weight of charge proposed is 15 cwt., which should under ordinary conditions give 12 cwt. of ingots. Taking the time of a single converting operation at half an hour it will be easy to obtain 50 blows per day, or a production of 30 tons. This may be easily increased by placing a second converting crane on the other side of the furnace, for which the same blowing-engine will be sufficient, as the actual blowing time will not exceed twelve minutes. The labour required for each converter will be about six men per shift.

The blast required has been experimentally determined at 40–50 cubic metres per minute at 15 lbs. pressure. This will be supplied by a single cylinder engine of 900 millimetres blast- and 786 millimetres steam-piston diameter 786 millimetres stroke, making fifty revolutions per minute, which is also to work a Root blower, and the accumulator pumps. Having regard to these very different demands upon the power of the engine, it will be provided with expansion-gear, allowing a considerable variation in the cut-off. A single boiler of 70 to 75 square metres heating-surface will be sufficient. The accumulator is intended to work at 300 lbs. pressure.

The cost of the plant, including one of each of the following items:—converter, converter-truck, blowing-engine, accumulator, ingot-crane, centesimal weighing-machine, and accumulator-pump, as estimated at £2,050 to £2,100; and that of the steam boiler, £325. The buildings may be of the simplest and cheapest possible character. As the productive power of such a plant contrasts very favourably with its cost, the Author considers that it may be fairly expected to meet the competition of large works, especially in the manufacture of a high-class product.

H. B.

Physical and Chemical Tests of Steel. By Pedro G. Salom.

(Transactions of the American Institute of Mining Engineers, vol. xii., 1883–84, p. 631.)

The results of tests, physical and chemical, of steel for boiler-plates and ship-plates, by the Author, at the Chester Rolling Mills, have, he considers, developed some points respecting the nature and strength of steel, which are more or less novel. The test-pieces were of two forms—the 8-inch and the 1-inch. In the first-named, having a total length of 20 inches, a straight part 1¼ inch wide and 8 inches long, is connected to the square ends by curves of about 1½ inch radius. In the second, two semi-circular notches, of ½-inch radius, are cut, opposite to each other, in the edges of the test-bar, which is 2 inches wide and 10 inches long, having a width of 1 inch at the middle of the length of the piece. The results of the tests are tabulated in detail.

The Author refers to the influence of carbon, manganese, phosphorus, and silicon, on the physical qualities of steel. The average proportion of phosphorus is 0·039 per cent.; the highest proportion is 0·075, and yet the heats in which this proportion occurs give excellent results, showing 54,900 lbs. and 57,820 lbs. tensile strength per square inch, with elongations of about 30 per cent. in 8 inches. Conversely, with a low proportion of phosphorus, the elongations are only 25·3 and 19·7 per cent. It is concluded that the combination of phosphorus up to 0·075 per cent. is not very injurious to the physical properties of soft steel.

The average of carbon is 0·15. The influence of carbon is more regular than that of phosphorus. The average of manganese is 0·38 per cent. The highest proportions are 0·73 and 0·58 per cent., in two instances, in which there are high tensile strength and low elongation, the carbon being above average. The manganese increases or diminishes with the carbon, and the tensile strength in direct proportion to both. There is a variation of carbon before and after the addition of ferro-manganese, ranging from 0·01 per cent. to 0·10 per cent.

Silicon prevents carbon from combining with iron. The importance of this fact was discovered by Colonel Caron. Phosphorus acts in a similar manner, and the Author is led to the conclusion that phosphorus and silicon in steel are not hardeners, but are injurious, in keeping carbon in the graphitic state, and, like graphite, in separating the particles of the metal. The conclusion is confirmed by a study of Dr. Dudley's tests of rails.

The most important conclusion drawn from the series of tests is the necessity of uniformity in the methods of making physical tests. The consumer might as well not make any specifications, unless he prescribes all the conditions of testing—as, thickness of plate, size of test-piece, shape of test-piece, quantity of load, duration of stress. The Author looks forward to the prescription of chemical tests only.

D. K. C.

Clémandot's Method of Tempering Steel by Compression.

By A. Carnot.

(Le Génie Civil, July 1884, p. 216.)

Mr. Clémandot's method consists in heating the metal till it acquires sufficient ductility, and applying great pressure while it cools. This operation modifies the structure of the metal, and imparts to it qualities similar to, though not identical with, those developed by tempering. The resulting metal differs very sensibly from that which is cooled naturally, the grain being much finer, and the hardness and resistance to rupture much greater. Two different and almost simultaneous effects are produced—first, energetic and continuous compression; second, rapid cooling. The latter is caused by contact with the plates of the hydraulic press. Its effect is similar to that produced by cooling in water, while that of the compression resembles the effect of hammering. It is sufficient if the pressure is applied to two faces only. The steel should be heated to a cherry red, and the pressure be brought to the required point (which may be 6, 12, or 19 tons per square inch) as rapidly as possible. In tempering by immersion the volume of the steel is increased and its density diminished, but this is not the case in the new process. The metal becomes very hard without losing its ductility, especially in steels with a large percentage of carbon.

Hitherto there has appeared a slight inferiority in the magnetic properties of the compressed steel, but this is compensated for by other advantages. It is well known that water-tempered steel when re-heated to redness returns almost to its natural state, and loses its magnetic properties. This is not the case with that tempered by compression, which can be re-heated, and even forged, without becoming demagnetized. This steel also retains the fineness of its grain after re-heating. Thus a bar of steel bent into a U-shape and then compressed, and a bar of the same weight compressed when straight, then re-heated and bent at the forge to the same shape as the first, would each support about twenty times its own weight, after having been magnetized to saturation.

It is thought that the magnetic force might be increased by submitting a bar already compressed to a second compression after forging; and bars that have been compressed may afterwards be tempered in water, and be converted into powerful magnets.

W. H. T.

On Qualitative Tests for Steel Rails. By L. Tetmajer.

(Stahl und Eisen, 1884, p. 608.)

This memoir is the first of a series upon the unification of nomenclature and classification of building materials, undertaken by the Author at the request of the Swiss Engineers' and Architects' Union. For its preparation, numerous mechanical tests have been made upon steel rails, both good and bad taken from the Swiss railways, while the corresponding chemical analyses have been made by Dr. Treadwell in the Polytechnic Laboratory, at Zurich. The results are given for twenty-two examples, about one-half of which have stood well, while the remainder have either broken, split, or suffered considerable abrasion in wear; but in many instances the mechanical test of tensile strength, elongation, and contraction, and the figures of quality (Wohler's sum and Tetmajer's coefficient) deduced from these have varied very considerably for the results obtained in practice. The best wearing rails, which often give contradictory results with the tensile test, were comparatively pure manganese steels, low in silicon, only exceptionally up to 0·2 per cent., but generally below 0·1 per cent., and with less than 0·1 per cent. of phosphorus and sulphur. On the other hand, rails with a tendency to break or split are low in carbon, with variable proportions of manganese, but contain much silicon, 0·3 to 0·9 per cent., and often above 0·1 per cent. of phosphorus. Another series of experiments upon rails for the Finland lines, made by the Author in 1879–80, shows the high quality of manganese steel. These are essentially highly carburized (0·3–0·4 per cent. carbon) with 0·7 to 1·4 per cent. manganese, and have stood three and a half years' wear without a single one being broken; while those of silicon steel with 0·106–0·144 per cent. carbon, 0·592–0·828 manganese, and 0·423–0·435 silicon, have failed in many cases, showing a great tendency to split. In both of the latter instances, however, the figures deduced from tensile tests of both good and bad specimens were substantially the same.

The causes of the difference between the two kinds of steel the Author attributes to differences in the structure of the ingot due to the agent used in "chemical consolidation," which may be either manganese or silicon, which structures are illustrated by photographs of ingot fractures. When silicon is used there is a tendency to unsoundness about the exterior of the ingot, which is surrounded by a honey-comb-like cellular casing of greater or less depth; while with manganese, the vesicular cavities are more or less dispersed through the whole substance, or concentrated towards the interior of the ingot. Rails made from the former are, therefore, more likely to contain unsound portions near the outer wearing surface, and to give unsatisfactory results in wear, than those from the latter; but as the test-pieces are usually cut from the centre of the rail-head, the tensile resistance of the inferior may be equal to or surpass that of the superior material.

In summing up his observations the Author concludes that the method of tensile testing is mainly of value in determining the quality of the material, but that for the finished product properly arranged falling-weight tests are necessary. He also considers that the test-pieces should be flat bars of 2·5 to 3·5 centimetres in area, cut as near as possible to the outer surface of both head and foot of the rail. He reprobates especially the research for microscopic imperfections (*mikrobensücherei*) upon the fractured surfaces, as an annoyance to the producer, and perfectly useless to the consumer. H. B.

Instrument for Measuring the Wear of Rails.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xxi., 1884, p. 161.)

The principle on which the construction of this instrument is based is that the ends of a straight line, moving in the direction of, and equal in length to, the straight line joining the centres of two circles of equal radius, one of which rotates about the other, describe like figures. In using the instrument, one end of an arm is carried round the rail whose wear is to be measured, the other end tracing the exact section on a zinc plate fitted to the instrument; if the section of a perfect rail be now traced on the plate, so as to coincide as far as possible with that of the worn rail, the amount of wear becomes immediately apparent, and the area of the section can be ascertained by means of a planimeter.

J. R. B.

Wear of Steel Rails. By — Coüard.

(Revue Générale des Chemins de fer, June 1884, p. 311.)

The Author refers to his previous communication on the Wear of Rails,[1] in which he maintained that the wear of rails, whether iron or steel, bears relation to the number of trains, and not to the tonnage; that the regular wear of steel rails diminishes with the convexity of the head of the rail; that after the passage of from fifty thousand to sixty thousand trains, the wear is not more than 1 millimetre, or $\frac{1}{25}$th inch per one hundred and ten thousand trains, on a straight and level line, clear of stations and tunnels: giving an average life of a hundred years for the rails on the Paris and Marseilles line, say ten times the life of iron rails.

On a straight line, the regular wear is greater on the outer rail than on the inner rail, or that next the interspace, for a double line of way. Steel rails wear less the harder they are: the more carburetted, the less flexible they are, and the greater the tensile strength. Hence the marked superiority of the rails of the Paris and Marseilles line over foreign rails.

On a line of double way, the wear is about one-half greater on the descending incline than on the ascending incline. The wear for one hundred and ten thousand trains may be calculated by means of the empirical formula $y = 1 + a x$, in which y is the wear in millimetres, x is the declivity in millimetres per metre, and a is a constant, of which the value, for inclines not exceeding 1 in 125, or 8 per 1,000, is 0·15 for descending inclines, and 0·05 for ascending inclines. On inclines steeper than 1 in 125, the values of a are respectively 0·36 and 0·20. On inclines exceeding 1 in 125, the brakes are applied to a more or less extent. On inclines near stations, where all the brakes are fully applied, the wear is greater, sometimes six times as much as is given by the foregoing formula.

In curves, on a level, the wear is from 60 to 74 per cent. greater for a curve of 330 yards radius than for a straight line; but on descending inclines the difference is very small. It is nothing where the ratio of inclination reaches 1 in 100; and the wear is even greater on the straight line than in the curve when the inclination is 1 in 40. On ascending inclines the wear appears to be the same as on level lines, that is to say, greater in the curve than on the straight line.

In tunnels, rusting is the greater as the ventilation is the less, and the tunnel the longer. In general, under ordinary conditions, the life of a steel rail in a long tunnel is from eight years to twelve years, irrespective of the traffic. The loss of weight by rusting is twice as much as that which corresponds to the wear of the upper surface of the rail.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxvii., p. 409.

Rails resist wear better, the harder they are. Bessemer steel appears to be superior to Siemens steel, and to dephosphorized (*phosphoré*) steel. But, in tunnels, where the rails are worn out by oxidation, the milder quality of steel for rails resists oxidation better than the harder qualities.

D. K. C.

Strength of Steel in the form of Beams and Struts.

By J. Christie.

(Transactions of the American Society of Civil Engineers, 1884, p. 253.)

This Paper is practically a continuation of the previous Paper by the same Author already noticed.[1] The steels which were subjected to tests of tension, compression, and transverse stress, were of two kinds, "mild" and "hard," both of them being Bessemer steel, of which the former contained from 0·11 to 0·15 per cent. of carbon, and the latter 0·36 per cent. The material was rolled at the Pencoyd Ironworks, where also the tests were made.

The tensile tests were made on pieces 24 inches long, cut from bars of different sections. Plates were clamped to these strips at a distance apart of 12 inches. The compressive tests were made on pieces 12 inches long inserted in a tube, which was filled up with fine sand.

It appears from the results of the tests that the elastic limits for tensile and compressive stress for each quality of steel are nearly equal per unit of section; and that, as was expected, the transverse resistance is approximately proportional to the longitudinal resistance. As the transverse elasticity of the different materials is nearly the same, the deflections of beams of iron and of steel of the same section are alike under equal loads within the elastic limits of iron. The following is a summary of the results of tests for longitudinal resistance in pounds per square inch:—

	Hard Steel (0·36 Carbon).	Mild Steel (0·12 Carbon).	Iron.
	lbs.	lbs.	lbs.
Ultimate tensile resistance . .	100,900	63,400	50,800
Tensile resistance at the elastic limit	56,700	39,400	31,200
Compressive resistance at the elastic limit	55,700	36,800	29,400
	Per Cent.	Per Cent.	Per Cent.
Ultimate elongation in a length of 8 inches	17·5	23·6	19·7

Several tests for the resistance of struts of angle- and beam-sections were made. The bars were prepared in the same manner as those before noticed. For the shortest struts, in which failure results entirely, or nearly so, from the effects of direct compression, the elastic tensile resistance of either iron or steel, which is practically equal to the resistance of compression, serves as a comparative measure of the strut resistance. Accordingly, small specimens, having a length only twenty times the shortest radius of gyration, gave resistances of about 100,000 lbs., 70,000 lbs., and 50,000 lbs. per square inch for hard steel, mild steel, and iron respectively, values which roughly approximate to the ultimate tensile resistances of these materials. As the transverse elasticity of steel does not vary much from that of iron, struts of steel and iron approximate towards equality of resistance as the proportional lengths are increased. Struts of mild steel and iron become equal in transverse elasticity when the length is about two hundred times the least radius.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxvii., p. 395.

Several Tables and diagrams of the results of tests accompany the Paper.

D. K. C.

Gold-Mining in South Carolina. By E. G. Spilsbury.

(Transactions of the American Institute of Mining Engineers, vol. xii., 1883–84, p. 99.)

The large areas of gold-bearing rocks in South Carolina are comparatively little known, as the produce of the mines in that State is usually disposed of at the United States branch mint in Charlotte, and has generally been credited to North Carolina or Georgia mines. Before the war numerous deposits were worked in more or less desultory fashion down the water-level, and then stopped, and operations have only been renewed after a long interval of years. At the present time, only four mines of importance are at work, namely, the Haile and Funderbank mines in Lancaster County, the Brewer, in Chesterfield County, and the West mine, in Union County. It is with the first of these alone that the Paper is concerned. The Haile mine is opened upon a deposit of talcose schist, metamorphosed in places to a quartzite, and impregnated with small crystals of pyrites and mispickel, which has been traced for more than three miles, and followed to a depth of 60 feet; the width averages 65 feet, and in the present bottom the ore is worth about 11 dollars per ton (equal to about 11 dwts.). The cost of extraction is very small, and, since the introduction of power drills, has been brought down to 80 cents. per ton. About one-third of the gold (3½ to 4 dollars) is free and can be recovered by battery amalgamation, the remainder being combined and more or less enclosed in the sulphides. The reduction is effected by a 20-stamp mill, the heads weighing 750 lbs., and making eighty drops of 7 inches per minute. With screens of forty to the inch mesh 35 to 37 tons of ore are stamped daily. The mortars are provided with inside plates, which are cleaned daily, yielding from

75 to 80 dollars' worth of amalgam. There are also 10 feet copper plates outside, which save about two-thirds more than the inside plates. Below the plate tables are a series of small *spitzkasten*, with an upward current of water which are found to be very effective in saving mercury that passes the plates. The slimes are then run over concentrators which save the sulphides, the final waste tailings showing a loss of less than 30 cents worth of gold per ton. The entire cost of milling and concentration is covered by 51 cents per ton, which is increased by 9 cents, the estimated wear of stamp heads and dies, to 60 cents.

The next process is the roasting of the concentrated sulphides which do not contain a trace of copper. This was supposed to be a matter of great difficulty, and a special furnace was designed for the purpose, consisting of a coil of 5-inch wrought-iron pipe 450 feet long, heated to low redness by an external fire, through which the finely-divided ore is blown with a large excess of air into suitable receiving chambers. When working properly, the calcination is most complete, scarcely the faintest trace of sulphur being left in the ore, and from the attrition of the particles among themselves, the gold is left bright and free from scale. Like other mechanical furnaces, however, it cannot be relied upon for perfectly uniform results, and therefore, the old long-bedded calciners have for the time been substituted by the Author. These are double-bedded furnaces 40 feet long and 5 feet wide, costing about £160 complete, with a roasting capacity of from 6 to 10 tons per day. With an average yield of 8 tons, the cost of roasting is about 1·10 dollar per ton.

The amalgamation of the roasted sulphides is effected in a barrel, by a modification of Designolle's process, in which nascent mercury, reduced from a solution of corrosive sublimate by metallic iron, is substituted for the liquid metal in the barrel. This has not realized the inventor's expectations as a method for treating raw sulphides, for which purpose it has, generally speaking, been a failure; but with roasted ores, the Author has found it to realize even more than was at first contemplated. The details of the operation are as follows:—A 600 lb. charge of roasted ore is placed in a cast-iron cylinder or barrel, containing about 1000 lbs. of cast-iron balls, which is then partially filled with water and half a gallon of bichloride solution is added. The barrel is then rapidly rotated for five minutes, when another half gallon of solution is added, and the rotation is continued for a further fifteen, at the end of which time every particle of gold is completely amalgamated. The contents of the barrel are then discharged into a large settler with a concave bottom, containing a bed of mercury. The pulp is kept in suspension by travelling rakes, which keep the surface of the mercury bed clear and ready to absorb the particles of amalgam immediately they are released and settle. The discharged pulp is passed first over revolving centrifugal copper plates, which catch suspended particles of amalgam, and lastly into a similarly arranged settler, in order to save the final traces of gold and amalgam. The simplicity of the whole process is remarkable; with a plant costing less than £800, 18 to 20 tons can be treated daily by one man and one boy. The whole cost of treatment, including chemicals, labour, steam, and depreciation of plant, is 38 cents per ton.

The standard solution used is of the following composition:—

Mercury bichloride, 1; common salt, 2; hydrochloric acid, 1 part. The proportion of acid is varied according as the gold is more or less rusty. These chemicals are diluted with water in such proportion that the solution contains 2 oz. of bichloride to the gallon, or 8 lbs. of the salt to 64 gallons of water. For ores containing less than $\frac{3}{4}$ oz. of gold to the ton, 1 gallon per charge is sufficient; but for every additional $\frac{1}{2}$ oz. a further $\frac{1}{2}$ gallon is added. The reaction that takes place is the following:

$$\text{Hg Cl}_2 + 2\,\text{Fe} = 2\,\text{Fe Cl} + \text{Hg}.$$

This result is due to the presence of chloride of sodium in the mixture. Otherwise it is probable that complete reduction would not take place at once; but the bichloride would be first reduced to the state of calomel Hg Cl, and then by a secondary action to mercury as above. The extreme rapidity with which amalgamation takes place is considered by the Author as due not so much to the above reaction, which is essentially a slow one, but to an electrolytic action set up in the acidulated bath, when any particle of gold comes in contact with iron, whereby the surface of the former is instantaneously covered by deposited mercury; and this action takes place even with rusty gold, when only a single point of the surface is clean so as to afford metallic contact. The action is indeed so rapid that, in ore containing 43 dollars per ton, showing freely in the pan before treatment, not a trace of unamalgamated gold could be found after the trituration with the solution had continued for ten minutes. The Author's results lead him to question the fact announced by Dr. Egleston, that gold particles whose surfaces have been condensed by hammering do not amalgamate readily, or rather, that such results are not obtained with gold from ordinary stamp-mills.

H. B.

The Telegraph Service and Electrical Signals on the St. Gothard Railway. By R. Séguéla.

(L'Électricien, September 1884, p. 251.)

This line of direct communication between Italy and Germany has been utilized by the Swiss Government for their telegraph service. The posts along the Saint Gothard Railway carry eight wires, four of which belong to the State and four to the Railway Company. The gauge of the wires is 4 millimetres, but the wire for the special international direct line between Berlin and Rome, with a relay-station at Bâle, is 5 millimetres in diameter. The posts are erected 60 metres apart; boucherized pine has been employed on the north side of the tunnel, and chestnut for the poles on the south side. The latter have not been injected, but they appear to last better than the poles made from pine. In the main tunnel, which pierces the Saint Gothard mountain, there is a cable 15 kilometres long, consisting of seven conductors each 1·84 millimetre in diameter, insulated with gutta-percha to 5·2 millimetres. The seven insulated cores are stranded together, covered with a hemp braiding, sheathed with eighteen wires, each 4·4 millimetres in diameter, and externally protected with a braiding of hemp, the total diameter of the cable being 33 millimetres. Two of the railway-service wires are for ordinary telegraph messages, and the remaining two for special electric signals, which are employed on two sections of the line, one of 90 kilometres between Erstfield and Biasca (including the main tunnel), and the other, 30 kilometres in length, between Bellinzona and Lugano. There are two systems of electric signals, consisting respectively of gong-alarms placed 1 kilometre apart along the side of the line, and a series of pedals fixed on the track at a distance of 1 kilometre from each other. The train in its passage over these pedals actuates a commutator, which is in connection with a registering apparatus at the station in advance. By this means the position and speed of the train are known to the officials.

The Author gives a description of the gong-alarms, which are similar to those employed on other continental railways. These apparatus are worked by galvanic batteries placed at every second station, a single battery being arranged to work the instruments on the north and south sides of the station. Two other batteries, one for the northern and the other for the southern end, keep a feeble closed-circuit current on the line. The gong-alarms are of two kinds, one being used outside stations, and the other at intermediate points along the railway. The closed-circuit current is too weak to move the armature of the electro-magnet in the intermediate-gongs, but permanently attracts that of the station-gongs. When signals are transmitted, the feeble line-current is interrupted by means of a commutator, thus releasing the station-gong armature, which now raises the detent of the clockwork. The latter is kept running by a weight, and the striking gear of the gong is brought into action. A special contact-wheel closes at short intervals the circuit of a local battery, the current from which is strong enough to attract the armature of the intermediate-gongs and set their clockwork in motion. The interruptions of the closed-circuit current are produced automatically in the station-gongs, but signals are sent from the intermediate-gongs by the manipulation, on the part of the signalman, of a key, which interrupts the current and starts the clockwork of the station-gongs. In order to avoid errors in signalling, contact disks are used at the station, the disk being mounted on a special axis which can be rotated at will. The periphery of each disk has projections or teeth, which during rotation move the lever of a commutator and thereby interrupt the current. The different disks make and break the current in such way as to produce certain combinations of strokes on the gongs, and the signals thus formed indicate certain phrases, such as; "train running towards the north," "train running towards the south," "stop all trains," &c.

The registering-apparatus at the station consists of a Morse ink-writer, kept in motion by a powerful thirty-six-hour clock. A register of the speed of the trains is obtained by means of the following arrangement. A battery at the station has its positive-pole always to earth, the other pole being to line through the Morse instrument. At each kilometre along the railway, a pedal in connection with a spring-commutator is placed near the rails, so that it can be depressed by the flanges of the wheels of a passing train. The commutator is enclosed in a box and when worked by the pedal, it puts the line to earth through the rails and completes the circuit. The armature of the Morse instrument is consequently actuated each time a wheel of the train depresses the pedal, and a series of marks are printed on the tape of the ink-writer, the marks being so close together as to produce a continuous line on the paper-tape at the time the train passes each kilometre post. The space between any two of these printed lines gives the speed of the train per kilometre. The tape runs out at the rate of 30 millimetres per minute or 1,800 millimetres per hour, and if x be the length of the space then $\frac{1,800}{x}$ will be the speed per kilometre. By means of a suitable scale the speed is read off at once without calculation.

The instrument-tape is carefully examined in the Inspector's office at Lucerne, and any infraction on the part of the engine-driver of the rule regarding the speed of the train is punished by a fine.

J. J. W.

The Preparation of an Indestructible, Self-Depolarising and Constant Earth-Connection. By JUSTIN MALISZ.

(Centralblatt für Elektrotechnik, vol. vi., 1884, pp. 440–42.)

A good earth-connection is of great importance for telegraphic purposes, and in the protection of buildings against lightning. The Author, after drawing attention to the defects of ordinary earth-plates, describes his method of preparing an earth-connection which conducts well, is self-depolarising, and has its junction with the line easily accessible.

A hole about 2 metres (6½ feet) deep, and about 1 metre square, is dug in the ground, and a layer of coke laid on the bottom, and firmly stamped down. A tube with its lower end resting on the coke is placed against one face of the hole, and filled tightly with coke, almost to the top. The hole is then filled up, and the earth rammed well round the tube, the upper part of which projects above the surface of the ground. A lump of coke or retort carbon, to which a copper band is rigidly attached by soldering or pouring molten lead over it, is put in the tube, and a final layer of coke pressed firmly round it. The copper band projects from the top of the tube, and to this band the line, or the lightning conductor, is soldered.

By this arrangement a constant earth-connection is obtained, as coke has a uniform conducting power under all circumstances, and its large surface ensures for the current an easy path to earth. The column of coke in the tube not only enables the junction between earth and line to be permanently above the ground and easy of access, but it has a depolarising action on the bottom layer of coke, thereby preventing the prejudicial effect of a counter electromotive force, which in so many cases renders an ordinary earth-plate useless.

The Author considers that the coke, which, in the upper part of the tube is in contact with the air, condenses oxygen, and can likewise absorb and oxidise the hydrogen formed by the current. The gases resulting from polarisation rise through the column of coke in the tube, and are dissipated in the air, and this column in virtue of its power of condensation plays an important part in the depolarisation of this form of earth-connection.

J. J. W.

On a probable Cause of Disagreement between the Electromotive Force and Thermo-Chemical Data. By G. CHAPERON.

(Comptes rendus de l'Académie des Sciences, Paris, vol. xcviii., 1884, p. 729.)

Amongst the voltaic elements, of which the actual electromotive forces present considerable differences with the theoretical electromotive forces, calculated from thermo-chemical data, a certain number exhibit phenomena due to the polarisation of the soluble or attackable metal. Several remarkable cases were pointed out by Becquerel in 1856, which the Author enumerates. Although it is usual to attribute such modifications of electromotive force as generally due to polarisation, it seems possible to the Author, *à priori*, that inherent properties of the metals, whatever else besides, which concur to produce this, also modify the static electromotive force. He has been induced to study, in their general form, the phenomena of polarisation produced by the metals iron, nickel, and cobalt, in an alkaline solution. By reason of the possible effect of a layer of oxide, which would greatly alter the conductivity of the electrodes, and itself cause a notable difference of potential, the experiments were conducted so as to avoid this effect. The results show that with some polarisable systems, such as those referred to, the difference of potential taken by the electrodes, where there is decomposition of the electrolyte into its elements, increases, according to a continuous law, between zero and the point of electrolysis, and even beyond.

To endeavour to define precisely the ratios that the Author has stated to exist between the phenomena of polarisation and the anomaly of the static electromotive force, let T_{mR} and T_{mH} be the work or electric energy corresponding, at a given pressure and temperature, to the absorption, or to the restitution, of the elements R and H of an electrolyte by a polarisable metal electrode *m*. T_{mR} and T_{mH} are not constants, but, on the contrary, vary within very wide limits, diminishing proportionally as the absorbed quantity of the elements R and H increases. The chemical work corresponding to the electric energy restituted by two polarised electrodes will generally be—

$$T_{RH} = T_{mR} - T_{mH},$$

T_{RH} being, under given conditions, the energy of formation of the electrolyte. If the polarisation follows a continuous law, as has been stated by the Author for the systems studied by him, this value of the chemical energy will vary from T_{RH} to zero between the point of electrolysis and the state of neutrality of the electrodes, which is then characterised by the equation—

$$T_{RH} - T_{mR} - T_{mH} = 0.$$

It is the limiting value of T_{mR} satisfying this equation that enters into the theoretical calculation of electromotive forces by means of the heat of combination.

P. H.

New Alkaline-Liquid Battery.

Prof. RUGGERO FABRI and G. RAVAGLIA.

(La Lumière Electrique, vol. xiii., 1884, pp. 8–9.)

The Authors, whilst acknowledging the merits of the Lalande and Chaperon oxide of copper battery, are persuaded, after lengthened experiment, that the oxide of copper may be suppressed with advantage, taking instead, as positive pole of the battery, retort carbon reduced to small fragments. Retort carbon is preferable to coke, but very satisfactory results have been obtained with the latter. Although it is difficult to suppose with the carbon any action that may be strictly termed chemical, experience has shown to the Authors that such a positive element is not easily polarised, even when the cell is kept a long time in action on closed circuit. The form of battery preferred by the Authors consists of a rod of zinc, carefully amalgamated, immersed in a solution of caustic potash in a glass cell, as in Leclanché's element. The positive pole is a cylindrical, very porous pot, the sides of which are pierced with numerous holes of sufficient size to allow the liquid to penetrate without admitting the pieces of carbon to pass. In the centre is a small carbon rod, or plate, or thick wire of copper, as an electrode.

When the battery is put in action, it develops a considerable electromotive force, attaining as much as 1·6 volt; but this rapidly diminishes to a limit which depends upon the relation of the resistance of the external circuit to that of the battery. With an external resistance of some ohms, a regular working is obtained differing but slightly from one volt. The great advantage of this battery, as of that of Lalande and Chaperon, is the low internal resistance, which admits of obtaining very large currents with relatively low electromotive forces. In this point it appears advantageous to substitute carbon for metallic oxides that have a lower conductivity.

P. H.

Planté Accumulator. By Paul Samuel.

(La Lumière Electrique, vol. xiii., 1884, pp. 89–90.)

In a recent form of this accumulator the plates of lead are arranged horizontally in a wooden box coated with gutta-percha. The plates are separated by laths of paraffined wood; and the odd and even plates are severally connected to form an electrode, each plate being bent at the side of the box at right angles, and brought above the surface of the liquid. For a medium size of accumulator the dimensions of the plates are 0·40 metre long, 0·30 metre wide, 0·001 metre thick, separated by 0·01 metre. Plates of very large size may be thus arranged, and great surface obtained in small space.

P. H.

Alternate-Current Machines and Self-Induction.

By E. Hospitalier.

(L'Electricien, vol. viii., 1884, pp. 289–298.)

The Author points out that the theory of alternate current machines propounded by Mr. Joubert in 1880, is applicable to machines of this class without an iron core; the inductors for each experiment being excited separately by a constant current, susceptible, however, of variation in order that the intensity of the magnetic field may be changed. As regards the induced and inducing circuits, it has been demonstrated that the current traversing the former has not, either on opening or closing this circuit, any action on the latter, the whole effect being due to the reaction of the induced system on itself. Mr. Joubert has shown experimentally that the law of the variations of electromotive force in these machines may be expressed by the simple harmonic term

$$E_t = E_o \sin \pi \frac{t}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where E_t is the electromotive force at time t; E_o its maximum value during the period; t the time reckoned from the moment when the electromotive force is nil, and T one complete half-period, that is, the time in which the electromotive force starts from and returns to zero without change of direction.

The theoretical investigation of alternate current machines, in which the self-induction may be neglected, is exceedingly simple. The value of the current at time t—taking t between nil and T—reckoning from the moment at which the current is nil, is

$$I_t = \frac{A}{T} \sin \frac{\pi}{T} t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where A is a constant depending upon the type of machine.

The total quantity of electricity induced in the time T, or a half period, is expressed by

$$Q = \int_o^T I \, d\, t = \frac{A}{T} \int_o^T \sin \frac{\pi}{T} d\, t$$

$$Q = \frac{2\, A}{\pi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and taking I_m as the value of the mean current, then

$$I_m = \frac{2\, A}{\pi\, T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

From this value of the mean current may be deduced that,

An electro-dynamometer inserted in the circuit of an alternating current machine, does not indicate the exact mean value of the current.

When the instrument is so joined up that the fixed and movable bobbins are in series, the direction of the current will be changed in both at the same time, and the "couple" will be at each instant proportional to I^2, or in this particular case,

$$\frac{A^2}{T^2} \sin^2 \frac{\pi}{T} t.$$

If T be small in comparison with the period of oscillation of the movable coil, then the couple will be the same as that produced by a constant continuous current I', or

$$I'^2 = \frac{1}{T} \int_o^T I^2 \, d\, t = \frac{A^2}{T^3} \int_o^T \sin^2 \frac{\pi}{T} t \, d\, t,$$

which when integrated gives

$$I'^2 = \frac{A^2}{2\,T^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5)$$

and combining equations (4) and (5) there results

$$I_m = \frac{2\sqrt{2}}{\pi} I' = 0 \cdot 9\, I',$$

which shows that the current indicated by the electro-dynamometer is greater than the actual mean value, which value can only be determined correctly by multiplying the readings of the instrument by 0·9. Suppose, for instance, that a continuous current, when feeding a certain number of incandescence-lamps in multiple arc, shows a reading of 9 amperes, then the electro-dynamometer must indicate 10 amperes if alternate currents be employed to obtain the same luminous power.

As regards alternate-current machines, the self-induction of which has to be taken into account, let R be the total resistance of the circuit; I the current at time t; E the total electromotive force of the machine, and U the coefficient of self-induction of the entire circuit, or the number which multiplied by $\frac{d\,I}{d\,t}$ gives the value of the electromotive force opposing at each moment the increase or decrease of the current, then

$$R\,I = E - U\frac{d\,I}{d\,t} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

and assuming that the machine follows the law of sines

$$E = \frac{E_o}{T} \sin \frac{\pi}{T}\, t \, . \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

where T is the duration of a complete half-phase, and E_o the maximum value of the total electromotive force when the speed is such as to give only one complete period in two seconds, t being taken at the moment when E is nil. Substituting this value in equation (6) we have

$$U\frac{d\,I}{d\,t} + R\,I = \frac{E_o}{T} \sin \frac{\pi}{T}\, t,$$

and the integration of this expression gives for the value of the mean current I_m during the phase

$$I_m = \frac{2\,E_o}{\pi\sqrt{R^2\,T^2 + \pi^2\,U^2}} \quad . \; . \; . \; . \; . \; . \; . \quad (8)$$

The effect of the self-induction is to reduce the value of the current in the proportion of $\frac{E_o}{\sqrt{R^2 T^2 + \pi^2 U^2}}$ to $\frac{E_o}{R\,T}$ and produce a retardation of phase, the value of which in seconds is a function of the duration of this phase. Thus for each total resistance R a decrease in the duration of the phase T, or in other words, an increase of speed, brings the current near the limiting value

$$I = \frac{E_o}{\pi U} \sin\left(\frac{\pi}{T} - \frac{\pi}{2}\right) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (9)$$

This value is independent of the resistance, and its retardation of phase is $\frac{T}{2}$ seconds, or equal to one-fourth of the complete period. Integrating the expression (9) for a half period, and dividing by the duration of this half-period T, then the mean maximum current is given by the formula

$$I_{m\,m} = \frac{2\,E_o}{\pi^2\,U} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (10)$$

and the mean value of the total electrical energy deduced from the preceding formulas is

$$A_m = \frac{1}{T} \int_o^T E\,I\,d\,t,$$

which being solved gives

$$A_m = \frac{1}{2} \frac{E_o^2\,R}{R^2\,T^2 + \pi^2\,U^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (11)$$

This expression shows that the total electrical energy in the circuit is a maximum for a given speed and value of I, as

$$R = \frac{\pi\,U}{T}.$$

For a given resistance, the power becomes greater as T becomes less, that is, the speed is greater.

When the value of R satisfies the relation

$$R = \frac{\pi\,U}{T}$$

the conditions of maximum work are attained, and the retardation of phase is then equal to one-eighth of a complete period, or to $\frac{T}{4}$. The formulas show that by doubling the speed the electromotive force is increased twofold; but the current is not doubled, nor is the power of the machine quadrupled.

In the foregoing investigations it is assumed that the copper wires are the only conducting bodies which are displaced in the magnetic field, but in some alternate current machines the bobbins have iron cores, either solid or composed of thin plates, and the Author points out that the theory of such machines has not yet been completely worked out, a number of facts respecting them have, however, been brought to light by the experimental researches of Dr. Hopkinson and other investigators.

J. J. W.

On the Measurement of Alternating Currents. By FRANK GERALDY.

(La Lumière Électrique, vol. xiii., 1884, pp. 321–325.)

The Author enters into a general discussion on the status and use of alternating-current electrical machines, and points out that there are difficulties in their practical accurate measurement. With instruments containing iron cores no accuracy is to be theoretically expected, but the electro-dynamometer is capable of greater precision. The electrometer, for the measurement of electromotive force, as carried out by Joubert's method, leaves little room for criticism; but the Author lays stress on the need of great care in all measurements connected with alternating currents. In the works of the Jablochkoff Company (Paris) it was desired to test a cable to be employed in an installation. The "candles" were arranged in the workshops, to which the cable was led in every way as for the installation, except that to save space the cables were kept coiled. The candles would not light at all; the current was completely annulled. It was found that the several coils, reacting on each other by induction, absorbed all the power of the generator. The cable was unrolled, and all worked well. In subsequent experiments by Messrs. Maquaire and Street, it was found that in place of a bobbin having 65 metres of wire of 1·7 millimetre diameter, and presenting a resistance of 0·05 ohm, and not including any iron, it was, with an alternating current of 4·8 amperes, necessary to substitute a rectilinear resistance of 1·41 ohm. Instead of a bobbin detached from a Maquaire alternating-current machine, and having 450 metres of wire of 1·4 millimetres diameter, presenting a resistance of 5·2 ohms, and surrounding two light plates of iron, it was, for a current of 6·03 amperes, necessary to put in a resistance of 175 ohms, and for a current of 7 amperes a resistance of 210 ohms.

These figures show how utterly false are calculations according to ordinary rules as applied to alternating currents. Suppose, for example, an alternating Gramme dynamo giving a current of 9 amperes, its armature has a measured resistance of 4·95 ohms, and it would be stated that this armature consumed $4{\cdot}95 \times 9^2$, or 400·05 watts. Now direct experiment proves that with an alternating current of 9 amperes, the armature circuit of the Gramme dynamo is equivalent to 108 ohms; the quantity of watts absorbed should then be accounted as $108 \times 9^2 = 8{,}748$ watts. Actually, no calculation founded on the laws of continuous currents is applicable to alternating currents.

P. H.

The Cost of recent Installations of Electric Light in Paris.

By P. CLEMENCEAU.

(La Lumière Électrique, vol. xiii., 1884, pp. 44 to 46.)

This is an examination into the cost of lighting the "Magasins du Printemps," and the "Hotel des Postes." In the former case, to obtain the same lighting with gas, the engineer, Mr. Delahaye, reports, would cost three times and a half as much as by electricity, and this amount of lighting could not be applied with gas, because of the heat and alteration of the atmosphere produced by gas. These conclusions, it appears, have been accepted by the Gas Congress. In the latter case, the cost of gas per carcel-hour is given at 0·431 franc; and the same electric light at 0·344 franc.

P. H.

On Electro-dynamometers. By G. CHAPERON.

(L'Électricien, vol. viii., 1884, No. 85, pp. 337–442, and No. 86, pp. 386–389.)

The Author points out that the instrument most frequently employed for the industrial measurement of alternate currents is the electro-dynamometer. The mechanical action between its fixed and movable coils is sufficiently strong, and the essential condition for procuring comparable results in various cases is attained, viz., that this action can be easily measured or balanced without employing coils with a large number of convolutions. If used, however, as a voltmeter for measuring the difference of potential of two points in a circuit, the instrument must have a high resistance, which can be obtained either by diminishing the section of the wire composing the coils, or increasing the number of convolutions. In the former case, the current traversing the dynamometer becomes very feeble and the mechanical action, which varies as the square of the current, soon ceases to be perceptible, and in the latter case, the coefficient of self-induction is considerably augmented, and the instrument can only be used for comparing variations of potential of the same period and form. The Author refers to the investigations and formulas of Mr. Joubert, which show that, in the construction of an electro-dynamometer of high resistance, the difficulty is to augment this resistance without increasing in the same ratio the coefficient of self-induction, and diminishing the sensibility too much. In order to overcome this, the Author suggests that the electro-dynamometer might be composed of two flat disks spirally covered with fine wire and mounted very close together, as in the electro-dynamical balance of Mr. Lallement. If a current is made to traverse the two spirals in contrary directions, the coefficient of self-induction for the whole system will be very feeble, but the repulsive force of the disks will be so strong that it can be measured by the torsion of a spring or other method. Instead of measuring this force, the deflection of a light coil, or a piece of soft iron of small magnetic inertia suspended between the disks, can be read off. The second plan would be preferable, if the disks were required of such weight and volume that the suspension of one of them would prove inconvenient. In place of the disks, two flat bobbins in close contiguity can be employed, and so arranged that a movable system can be easily suspended between them.

In an apparatus of this kind, it is important to know what error has been introduced by neglecting the ratio, or rather the square of the ratio of the coefficient of self-induction to the resistance. The Author describes the method adopted by him for determining the limit of this error, and the coefficient by which any current passing through a given coil must be multiplied to obtain the total quantity of electricity traversing the wire during the period of the extra-current or time during which this current must circulate in the coil to furnish the same amount of electricity as that due to the final impulse.

In a continuation of the Paper, the Author gives diagrams descriptive of the type of electro-dynamometer devised by him. In the directing field, formed by two fixed coils placed close to each other, and arranged so that the current traverses them in opposite directions, is suspended bifilarly a disk of varnished cork wound spirally with about fifty convolutions of wire. The position of equilibrium of the disk must be made to coincide with the plane of separation of the coils. By means of a mirror fixed to the disk, the deflection of the latter can be determined and the strength of the directive force evaluated. For leading the current into the movable circuit, the two suspension wires may be employed, as in Weber's apparatus, but as their length must be considerable, in order to avoid heating, this method is inconvenient. Mercury contacts in the case of instruments of high resistance are difficult of adjustment. The Author has found that the following device gives good results: the two ends of the wire forming the movable coil are soldered to two fine copper wires, shaped like a two-pronged fork; the extremity of each prong dips into a jar filled with a saturated solution of cupric sulphate, the current being led from the fixed coils to copper electrodes suspended in the jars. As the instrument is employed for the measurement of alternate currents, no inconvenience arises from the electrolyte.

This form of movable circuit is absolutely astatic, and therefore insensible to terrestrial magnetism, or even to any more powerful magnetic field in which it may be placed. The Author has also employed for the movable system a light disk of soft iron, making an angle of some degrees with the plane of separation of the two fixed coils. With a disk 0·1 millimetre thick pierced in the centre, and having radial slits, sensible deflections are obtained from a current of less than the two-thousandth part of an ampere, or an electromotive force of half a volt at the terminals, the coils being joined together in derived circuit.

J. J. W.

On a Mercury Electro-dynamometer. By G. Lippmann.

(Comptes rendus de l'Académie des Sciences, vol. xcviii., 1884, p. 1534.)

A small parallelopipedic chamber, filled with mercury, is arranged at the centre of a coil of copper wire. The electric current to be measured traverses successively the wire of the coil and the plate of mercury; this besides communicates laterally with the two branches of a manometer. When the electric current is set up, the manometer deflects permanently, by virtue of the electro-dynamic action exerted on the plate of mercury by the rest of the circuit. This instrument has the properties of an ordinary electro-dynamometer; it measures the square of the quantity i of the current, and permits of measuring alternate currents. As all the parts except the mercury are rigid, the apparatus once constructed and graduated preserves its form, and serves in all places without new measures; it is equivalent to a standard of quantity. It may be arranged to give absolute measures. The pressure p, indicated by the manometer, is connected to the quantity i by the formula

$$p = \frac{C}{\epsilon} i^2,$$

in which ϵ represents the thickness of the plate of mercury, C the intensity of the magnetic field produced at the centre of the bobbin by a unit current, deduced from the dimensions of the bobbin. Once these dimensions are known the instrument may be graduated *a priori* by the formula.

P. H.

Mechanical Depolarization of Galvanic Batteries. By V. Bablon.

(L'Électricien, September 1884, p. 207.)

In the arrangement proposed by the Author for the depolarization of a battery, the negative element consists of an endless metallic band stretched like a strap between two rollers, one being placed at the bottom of the battery, and the other, or motor roller, at the top. The latter is situated at such a height above the surface of the liquid that the band at the speed it travels has its upper portion out of the liquid, and in contact with the air sufficiently long to ensure a certain amount of depolarization. This action may be assisted by means of fixed brushes or rubbers, so situated that they press against the band and remove any drops of liquid adhering thereto, thus ensuring a better contact of the metallic surface with the oxygen of the air. The zinc plate is fixed between the inner faces of the moving band, and two other positive plates can also be arranged opposite its outer faces, in order to increase the active zinc surface of the battery. The arrangement is susceptible of various modifications, and the rollers may be arranged so that the metallic band would have a horizontal in place of a vertical motion.

J. J. W.

The Measurement of the Internal Resistance of Galvanic Batteries by means of the Telephone. By G. Chaperon.

(L'Électricien, September 1884, pp. 241–244.)

The method described by the Author of measuring the internal resistance of a battery is similar to Mance's, but a telephone is used in place of the galvanometer. A rectilinear rheocord, consisting either of a German silver, or platinum wire, 0·1 to 0·2 millimetre in diameter, forms the A and B branches of a Wheatstone bridge, the two opposite branches containing respectively a set of comparison coils R and the battery P, the internal resistance of which has to be measured. A telephone T replaces the galvanometer in the centre diagonal, and the outer diagonal is joined at one end to a platinum slider, which can be placed in contact with any point of the slide wire resistance or rheocord. The resistance of the centre diagonal and telephone T may be high, and that of the outer diagonal is also chosen arbitrarily. The test is made by depressing a key inserted between the junction of the outer diagonal with the branches containing the coils R and battery P, and, a few seconds after the first flow of the current, touching the rheocord at various points along its length, with the platinum slider, until a position N is found where the sound in the telephone produced by the contact of the two wires is a minimum, then the equation

$$\frac{x}{R} = \frac{B\,N}{A\,N}$$

gives the internal resistance of the battery. As the branches of the bridge have a high coefficient of self-induction, it is impossible to find a point on the rheocord at which there is a complete absence of sound in the telephone. The self-induction is, however, diminished by using a straight wire for the rheocord; the wire for the comparison coils must be wound double, and none of the connection-wires should be twisted helically.

The measurement of the resistance of wires, either in coils or straight lengths, can be likewise made by means of the telephone. In this case there is no disturbing influence like that caused by the electromotive force of the battery. The telephone T for such tests is placed in the outer diagonal, the resistance to be measured replaces the battery-cell P, and one or two Daniell's cells occupy the centre diagonal in place of the telephone. The circuit of the bridge must be closed a second or two before the point N is found. In this test there is no current passing through the instrument, whatever self-induction there may be in the other branches and in the resistance to be measured, consequently the point N is determined directly there is an entire absence of sound in the telephone. By this method the resistance of coils, induction bobbins, &c., can be measured to an accuracy of one half to one quarter per cent.

J. J. W.

An Electric Railway in Upper Silesia.

(Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, vol. xxxii., 1884, p. 286.)

At the Consolidated Paulus-Hohenzollern Coal-mine, near Beuthen, in Upper Silesia, an electric railway has been in use since September, 1883. In general arrangements it is very similar to that at Zaukeroda, but has larger engine-power and a greater working capacity, the latter being guaranteed by the builders, Messrs. Siemens and Halske, as equal to a transport of 500 tons net in ten hours.

The steam-engine, of 628 millimetres diameter of piston and 1,000 millimetres stroke, drives the dynamo directly by a belt from the rim of the fly-wheel, and is controlled by a patent steam-regulator. The length of the conductor, from the primary machine to the commencement of the line is 230 metres, and the distance thence to the present end of the line of traction, is 750 metres. The conductors on the first section are similar to those in Zaukeroda, namely, two insulated copper-wire cables, while those on the line are iron bars, with tinned ends and fish-plates, which are suspended by insulators from the roof of the cross-cut gallery in which the line runs. The locomotive, weighing 42½ cwt., travels either backwards or forwards without being turned.

With the steam-engine making thirty-four revolutions, fifteen loaded wagons may be drawn at a speed of 2·5 metres per second, which is increased to 4 metres with the same number of empty wagons. The latter weigh 9 cwt., and carry a load of 11 cwt., giving a gross weight of 20 cwt. per loaded wagon, or per train 15 tons gross and 8¼ tons net load. Experimentally the running time of a train, including hooking on and detaching, is found to be ten minutes, so that six trips can be made per hour, giving a net load transported of 50 tons in round numbers. The maximum duty obtained, however, at the above speed, up to the present time, is 17 tons gross per train, as the supply of coal from the workings is not sufficient to keep the locomotive fully employed.

H. B.

The Electro-magnetic Rotation of the Plane of Polarization of Light by Iron, Cobalt, and Nickel. By A. Rundt.

(Exner's Repertorium der Physik, 1884, p. 703.)

In 1877 Kerr discovered that the plane of polarization of a ray of light reflected normally from the pole of an electro-magnet is rotated through a small angle in the same direction as that of the magnetizing current. These experiments have been repeated by the Author, who has extended them by the production of films of the three magnetic metals, iron, nickel, and cobalt, of sufficient tenuity to be translucent, with which he has investigated the action of the current upon transmitted light. The films were produced by depositing the metals electrolytically upon glass plates which had previously been rendered conductors by a brilliant film of platinum which is so thin as to be fairly transparent. These platinized surfaces are used as rotating mirrors in König's acoustic apparatus.

The iron films were deposited according to Varrentrapp's method, and those of nickel and cobalt from solutions of their double ammoniacal sulphates. The colour of the light transmitted through iron is brown, varying in depth of tint with the thickness of the film; that through cobalt grey, and that through nickel grey, with a bluish tinge. Strips cut from an iron film, when magnetized by touch become permanent magnets which take a position in the plane of the magnetic meridian when suspended by a cocoon thread. The experiments were made with a Ruhmkorff electro-magnet, with conical perforated pieces attached to the poles, which were brought to within 4 millimetres of each other. The current furnished by a Gramme dynamo, averaged about 16 amperes intensity. The metal-covered disks were suspended between the poles by a holder, allowing a certain amount of adjustment vertically and horizontally, as well as about the axis of suspension, so as to ensure perpendicularity to the path of the ray. Solar light was used in every case. The rotation due to the glass was first observed upon a portion of the surface free from the electro-deposited film, *i.e.*, that covered with platinum, as it was found that the latter was without measurable effect, and then that due to the combined action of glass, platinum, and the deposited metal iron, nickel, or cobalt. As there was a tolerably strong chromatic dispersion perceptible in all cases, the observations were made with the middle part of the spectrum.

Four experiments are recorded with iron and cobalt films and two with nickel. The amounts of rotation with iron were 0°·54′, 2°·06′, 3°·30′, and 3°·42′, the first being a very thin film transmitting a pale brown light, while the last, which was thickened by a second deposit, gave a dark-brown tint. Three cobalt films gave 1°·06′, 1°·04′, and 1°·18′. When the first and second of these were combined, the joint rotation was 1°·88′. Two experiments upon good homogeneous nickel films gave 0°·39′ and 0°·49′ respectively. The rotation was in all cases positive, *i.e.* similar to the direction of the current.

In order to obtain an approximate numerical value for the specific rotatory power, the weight of an iron film, producing a rotation of 1°·48′, was determined, and from it the thickness was computed to be 0·000055 millimetre,produced as the platinized glass base, 1·61 millimetre thick produced a rotation of 1°·36′, the specific rotatory power of iron appears to be about 32,000 times that of an equal thickness of glass. Another film of 0·000069 millimetre gave a result equivalent to 35,000 times that of glass.

The specific rotatory power of cobalt is very near that of iron, while that of nickel is considerably lower. Two experiments gave it approximately as 14,000 times that of glass.

By the application of a method demonstrated by Righi, the Author computes the rotatory power of iron to be 1,462 times that of a similar thickness of quartz. The subject of the rotation produced in reflected rays from magnets is treated at great length in a subsequent part of the Paper. Kerr's experiments being repeated and supplemented by others, with cobalt and nickel mirrors. In a final paragraph, a summary of the facts, as far as known at present about the electro-magnetic rotation of the plane of polarization, are given as follows:—

1. The greater number of isotropic solid bodies, fluids and gases hitherto examined, produce positive rotation.
2. Concentrated ferric chloride solution has negative rotation, which is also the case with other magnetic salts, as apparent by their diminishing the positive rotation of the solvent.
3. Oxygen, which is comparatively strongly magnetic, has positive rotation, as determined by Röntgen and the Author.
4. The plane of polarization of light transmitted through iron, cobalt, and nickel is positively rotated.
5. Light perpendicularly reflected from the pole of a magnet is negatively rotated, according to Kerr; as is also that similarly reflected from surfaces of nickel and cobalt, according to the Author.
6. The rotatory dispersion produced by iron, whether on transmitted or reflected light, is anomalous, *i.e.* the rotation is greater for red than for blue rays.
7. The complex phenomena obtained by oblique reflection from the poles or side faces of a magnet may be attributed to the penetration of a thin film of the metal by the light previous to reflection, in which film a negative rotation is set up.

H. B.

Apparent Resistance of the Voltaic Arc in Lighthouses.

By F. Lucas.

(Comptes rendus de l'Académie des Sciences, vol. xcviii., 1884, pp. 98, 1040.)

The ordinary voltaic arc of lighthouses plays between the points of two carbons of 16 millimetres diameter, separated, by the action of a Serrin regulator, to 4 millimetres. The introduction of a voltaic arc in the circuit of an alternating current magneto-machine always produces a diminution of the mean quantity of current; it appears as that the arc were itself a conductor the resistance of which ζ was a function of two variables, the quantity of current I and the separation ϵ of the carbon-points; and this may be written $\zeta = \phi(I)\,\psi(\epsilon)$, ϕ and ψ being two unknown functions to be determined. By means of experiment the Author arrives at the empirical formula—

$$\phi(I) = 0{\cdot}40 \text{ ohm} \left(1 - \frac{I}{80 \text{ amperes}}\right) \quad . \quad . \quad . \quad (1)$$

and consequently

$$\zeta = 0{\cdot}40 \left(1 - \frac{1}{80}\,\psi\right)(\epsilon) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

It remains to determine the nature of the function ψ of the separation of the carbons. In his trials, the Author obtained with a separation appreciably nil 74·36 amperes, with 4 millimetres separation 58·17 amperes, with 9 millimetres 34·30, and with 10 millimetres the arc was extinguished. These results are expressed by the formula—

$$I = 75 \left(1 - \frac{\epsilon}{16{\cdot}67}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which ϵ may vary from 0 to 9 millimetres.

For each value of I, the total resistance R of the external circuit was given by the formula $R = \dfrac{106{\cdot}58 \text{ volts}}{I} - 1{\cdot}346$ ohm. Deducting from R the resistance of the cables and of the carbons—

$$\zeta = \frac{106{\cdot}58}{I} - \frac{0{\cdot}094\,I}{25 + 1{\cdot}21} - 1{\cdot}463 \quad . \quad . \quad . \quad . \quad (4)$$

the value of the special resistance of the voltaic arc.

Giving to ϵ a value between 0 and 9, I is obtained by formula (3); setting this value in formula (4), there is obtained ζ. Replacing I and ζ by their values in (2), the $\psi(\epsilon)$ is calculated; and there may be also deduced from experiment the values of $\psi(\epsilon)$

that correspond to values of the variable ϵ. Results thus obtained have led the Author to the empirical formula—

$$\psi(\epsilon) = 1 + \frac{\epsilon}{1 \cdot 4}.$$

Thus the resistance of the voltaic arc may be represented by the formula—

$$\zeta = 0 \cdot 40 \left(1 - \frac{1}{80}\right)\left(1 + \frac{\epsilon}{1 \cdot 4}\right).$$

With a current of 50 amperes, and a separation of 4 millimetres between the carbon-points, the normal conditions of the production of the arc in French lighthouses, the resistance of the arc is 0·58 ohm. P. H.

On the Origin of Atmospheric Electricity. By E. GERLAND.

(Elektrotechnische Zeitschrift, 1884, p. 292.)

The Author first refers to the theories of Mohn, Fick, Pouillet, Dove, Wettstein, Palmieri, Mühry, Becquerel, Werner Siemens, Holtz, von Bezolds, Dellman, and other physicists, regarding the source of atmospheric electricity. These theories may be classed under two groups, viz., one in which the earth is taken to be the source of this electricity, and the other comprising all the theories which regard the sun as the origin of the electrical phenomena observed in the earth's atmosphere.

Dove was the first to point out that electricity may be generated by the friction set up when aqueous vapour is formed in the midst of air. This was inferred from the fact that electricity is developed in considerable quantities when sand and dust are whirled about in the air.

Palmieri observed that atmospheric electricity increased as soon as the relative humidity of the air became greater. In a mist, the increase was more marked, and in hail, rain, or snow, the tension became so high that sparks were produced.

To the second group belong the theories of Becquerel and Werner Siemens. The former scientist assumes that the hydrogen given off by the sun is strongly electrified, the electricity in a diminished state of tension being carried into space by radiation until it reaches the earth. Goldstein's experiments have shown that such radiation, analogous to that of light and heat, is possible. Werner Siemens' hypothesis is based on Sir William Siemens' theory of the conservation of solar energy. The basis of this theory is that interplanetary space is filled with highly rarefied gaseous matter, which is drawn towards the polar surfaces of the sun, and during its approach thereto the gases composing this attenuated matter become compressed. On reaching the photosphere, these gases meet with such conditions of temperature and pressure as cause them to flash into flame. The products of their combustion flow towards the solar equator, and are by centrifugal force projected into space. Dissociation is then effected by means of solar radiation, and the gases resulting therefrom are again attracted towards the polar regions of the sun, and the cycle of operations repeated.

Werner Siemens assumes that the action of the gases on the photosphere produces enormous friction, the photosphere thereby attaining a high electric potential of positive sign, whilst the gases become oppositely electrified, and carry this electrification with them into space. As the earth and other planets are probably conductors, each of these bodies forms, in conjunction with the sun, a stupendous collecting apparatus, the insulating medium being the intervening empty space. The potential of the earth is dependent on that of the sun; terrestrial magnetism as well as the northern and southern lights, are mainly due to solar electricity.

Holtz has raised various objections to this theory, and the Author points out that it gives no satisfactory solution respecting the source of the electricity of thunder clouds, and does not take into account such phenomena as the diurnal electric variation and, at places where rain is falling, alternate zones of negative and positive electricity surrounding a positively electrified centre.

In the Author's opinion, these difficulties do not obtain when the earth is taken to be the source of the electricity of clouds, and this hypothesis would have been more generally accepted, had the fact been recognized that the generation of the observed positive electricity of a cloud implied the presence of an equally large quantity having a negative sign. Wettstein and Siemens are the only two physicists who have paid sufficient regard to this, and indicated by what means the negative charge is removed.

The careful observations of von Bezolds show that at the outbreak of a thunderstorm the atmospheric pressure is at a minimum, and the temperature at a maximum. The formation of the storm is due, therefore, to an ascending current of air, which is capable of rapidly separating the electricities. By means of this upward current warm and humid strata of air are conveyed to colder regions, where the aqueous vapour is condensed with more or less rapidity; this process is accompanied by a development of heat caused by the vapour giving out its latent heat of vaporization. The increase of temperature causes the layers of air to rise still higher, and the vapour becomes more rapidly condensed; raindrops are thus formed, and these drops fall quickly towards the earth. Their velocity relatively to that of the air becomes so great that electricity is generated, either through friction between the drops and the air, or through the formation of the drops, which are charged with electricity of one sign, whilst the air is electrified oppositely. If the velocity of the ascending air-current is sufficiently great, the potential of the cloud may become so high that a discharge takes place between it and other clouds or the earth; the latter having become negatively electrified by induction at that portion of the surface over which the cloud rests. The discharge may be effected gradually by the raindrops, or suddenly with the accompaniment of a flash of lightning, the nature of the discharge depending on the velocity of the current of air. The increased rainfall which often occurs after lightning may be ascribed to a sudden increase in the velocity of the air-current, and a consequent larger formation of raindrops. A greater quantity of electricity is thereby generated, and a sudden discharge to earth takes place, whilst the raindrops require a longer time to reach the ground. Palmieri found that the electrification of thunder-clouds was always positive, when no inductive effect was exercised. The phenomenon observed by Dellmann, viz., a cloud with a negative centre surrounded by a zone of positive sign, was no doubt due to induction.

The Author considers that the various circumstances which precede thunderstorms favour his theory that the source of the electricity is to be looked for in ascending currents of air which cause rapid condensation of aqueous vapour; and he describes, in support of his idea, the various phenomena observed during the thunderstorms of this latitude, which have, according to Dove, their origin in the ascending and descending equatorial currents of air. The Author proposes to add to these two classes a third, which shall embrace storms arising from predominant local currents, or summer storms. In Holland, he had, on a stormy evening in winter, the opportunity of observing a phenomenon, which appeared to negative the idea that the electricity of thunder-clouds was due to the inductive influence of the earth. The night was tolerably clear and starlit, when, at a certain moment, a cloud scarcely large enough to cover the constellation of Ursa Major was urged by the west wind quickly across the sky. The cloud had the form of a nine-pin, the point being turned towards the direction from which the wind was blowing. As several flashes of forked lightning passed from the base of the cloud to its point, each flash being followed directly after by loud peals of thunder, the cloud could not have been very distant, or of great extent. No rain appeared to fall from it, but there was scarcely light enough to determine this with certainty. On the supposition that the cloud was charged by induction from the earth, the springing across of the flashes from one part of the cloud to the other could only be accounted for by admitting that a marked change in the electrical condition of the earth took place before each flash, whereas the phenomenon is easy of explanation when attributed to an ascending current of air which caused a small quantity of cold air to be forced into the equatorial current.

J. J. W.

On the Absolute Value of the Horizontal Component of Terrestrial Magnetism at Paris. By Prof. MASCART.

(Comptes rendus de l'Académie des Sciences, vol. xcix., 1884, pp. 232–235.)

The mean value of the horizontal component (H) at the Observatory of Parc St. Maur, Paris, on the 1st July, 1884, is in C. G. S. units

$$H = 0{\cdot}19414 \pm 0{\cdot}00012.$$

As the greater errors generally correspond to magnetic disturbances indicated by the curve of variations, the probable error is, actually, slightly less and inferior to 0·0001.

P. H.

Measurement of the Horizontal Component of Terrestrial Magnetism by the Method of Damping.

By J. B. BAILLE.

(Comptes rendus de l'Académie des Sciences, Paris, vol. xcix., 1884, p. 704.)

The horizontal component H of terrestrial magnetism is ordinarily determined, in absolute value, by Gauss' method, which at the same time gives M, the magnetic moment of the bar. But this method necessitates two bars and two independent observations, separated by a long interval of time. The Author proposes a method based upon the fact that a magnetised bar, oscillating inside a coil of covered wire, experiences a very different "deadening," accordingly as the circuit is open or closed. Measuring the deadening, or damping in each case, the difference gives the moment h of the reaction of the induced currents exerted on the moving magnet. This element is connected to the magnetic moment of the bar M, and to the electrical constants of the coil (resistance in ohms W, and galvanometric constant G expressed in centimetres) by the known formula $M^2 = W\,G^2\,h$, from which M may be determined. And as the directing couple H M has already been determined by the period of oscillation, and from knowledge of the moment of inertia, the number H may be determined in absolute units (C. G. S. for example), if the other elements have been measured in corresponding units. The method is very simple and accurate; the Author gives comparative figures.

P. H.

A New Method for the Direct Measurement of Velocities.

By — SMRECKER (Mannheim).

(Wochenschrift des österreichischen Ingenieur- und Architekten Vereins, 1884, No. 37.)

The Author, in conjunction with Professor Harlacher of Prague, and Professor Henneberg of Darmstadt, has invented a method of directly measuring velocity, on the principle of comparing the velocity to be measured with a known velocity.

Any velocity v can be marked on the edge of a circular plate of radius ρ, rotating with an angular velocity w,

when $$v = \rho\, w.$$

If ρ is made constant, and the velocity v measured by the circular velocity w, we get empirical results, a fault of all the velocity-measurers which depend on the measurement of circular velocity through centrifugal force.

But if w is made constant—and a constant circular velocity may always be got by means of clockwork—the velocity is measured by the variable radius ρ, and the velocity to be measured is thus proportionate to a measurable length.

A is a flat circular plate revolving at a constant rate. The speed of revolution of any point on this plate increases of course with its distance from the centre. B is an indicating roller which touches the surface of the plate A. It moves freely upon the screw-spindle G, upon which it is screwed, and which is in the same plane as, and at right angles to, the axis of the disk A. If now the spindle C is connected with the shaft or motor whose velocity is to be measured, the speed of revolution of B will be proportional to that velocity. If the speed of revolution of the plate at the point of contact is not the same as that of the roller B, B will travel along the spindle until it reaches a point distant x from the centre of the revolving disk A, where the two velocities are equal. This distance x can be read off, and is the measure of the velocity.

W. B. W.

On the Crushing-Strength of Ice. By Colonel WILLIAM LUDLOW.

(Proceedings of the Engineers' Club of Philadelphia, May, 1884, p. 93.)

In 1880 and 1881, the Author had under consideration the construction of an ice harbour at the head of Delaware Bay. The harbour was designed as a quadrangular area inclosed between two lines of pier, each pier consisting of two lines, united at angles facing respectively up and down stream, with open entrances from the east and the west. The piers were to be built of trestles, each consisting of four piles, two upright and two inclined, screwed into the bottom, and suitably braced. The most formidable destructive agent would be floating masses of ice, and the crushing-strength of ice became a matter for inquiry.

In the report of a Board of Engineers in 1845, the effect of an acre of ice from 12 to 15 inches in thickness, moving with a velocity of 3 feet per second, impinging against a breakwater, was estimated to be such that a pressure of 27·11 tons would be directed against each square foot of front surface, equivalent, apparently, to a pressure of 425 lbs. per square inch. In another case, of the Illinois and St. Louis Bridge, a crushing-resistance of 600 lbs. per square inch was assumed.

The Author made a series of tests for the crushing-strength of ice by means of a testing-machine at Fort Tompkins, on Staten Island, in which pressures were indicated by gauges, and which had been used for crushing blocks of stone and cement. The ice blocks were procured from several sources—pond ice, Delaware ice, and clear masses from the Kennebec—cut, by sawing and rubbing, to 12-inch cubes and other smaller sizes. The temperature of the testing-room was taken; also that of the ice, in which a thermometer was imbedded, placed in a hole bored for the purpose. Small blocks of white pine were interposed to distribute the pressure. The specimens resolved themselves, under pressure, into small vertical columns, normal to the natural surface of the ice, which trembled slightly and compressed, until, in several cases, the block exploded with a loud report.

The results of the tests, which are tabulated, showed that, at from 23 lbs. to 30 lbs. pressure per square inch, there were evidences of yielding; and that the blocks were crushed at pressures of from 100 lbs. to 1,000 lbs. per square inch, for ice of the clearest and most compact structure, averaging 575 lbs. It was inferred that ordinary clear ice, like that of the upper Delaware River, would resist a pressure of 700 lbs. per square inch; and that such ice as that at Liston's Point would crush with from 400 lbs. to 450 lbs., or less, from its gradual disintegration by exposure. Also, a certain degree of buckling or yielding, through from ½ an inch to 1 inch, would take place before the final crushing; in so much cushioning the blow. The crushing datum, employed in computations for the construction of the pier, was taken at 400 lbs. per square inch. D. K. C.

Wickel's Warming- and Cooking-Stove. By U. R. Maerz.

(Gesundheits-Ingenieur, November 15, 1884, p. 671.)

This is an improvement upon the ordinary form of German glazed earthenware stove, the action of which depends, as is well known, upon the presentation of a large heating-surface to the passage of the products of combustion from the grate to the chimney. In the new stove the flue is surrounded by an air-flue passing alternately backwards and forwards in the same direction as the smoke-flue. The air-flue has direct connection with the exterior atmosphere below, and at its upper orifice is connected with a T-shaped pipe, one limb of which opens into the room, the other into the chimney, but the communication with the chimney can be closed at will by means of a damper. It is therefore possible to use the stove as a calorifer, when the damper leading into the chimney is shut, and to draw in external air and heat the same before admitting it into the apartment. Special arrangements are also made to enable the stove to be used for the extraction of foul air in summer, by means of an air-flue entering the furnace-chamber. By reference to diagrams an explanation is given of the mode in which this system can be applied for cooking stoves.

G. R. R.

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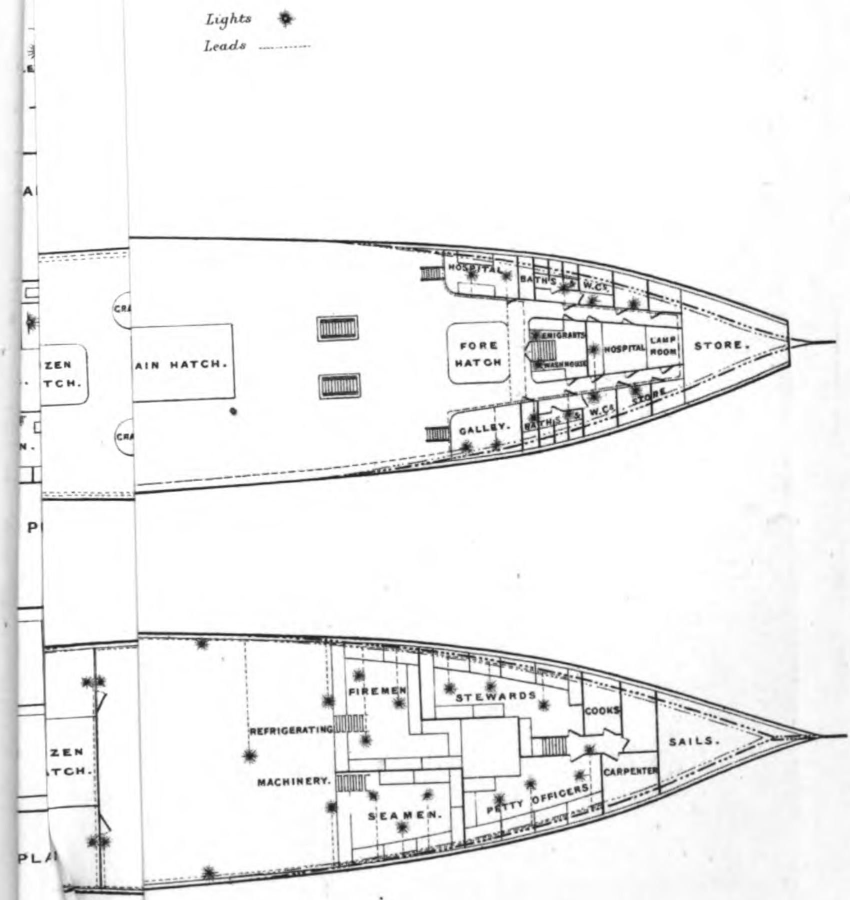
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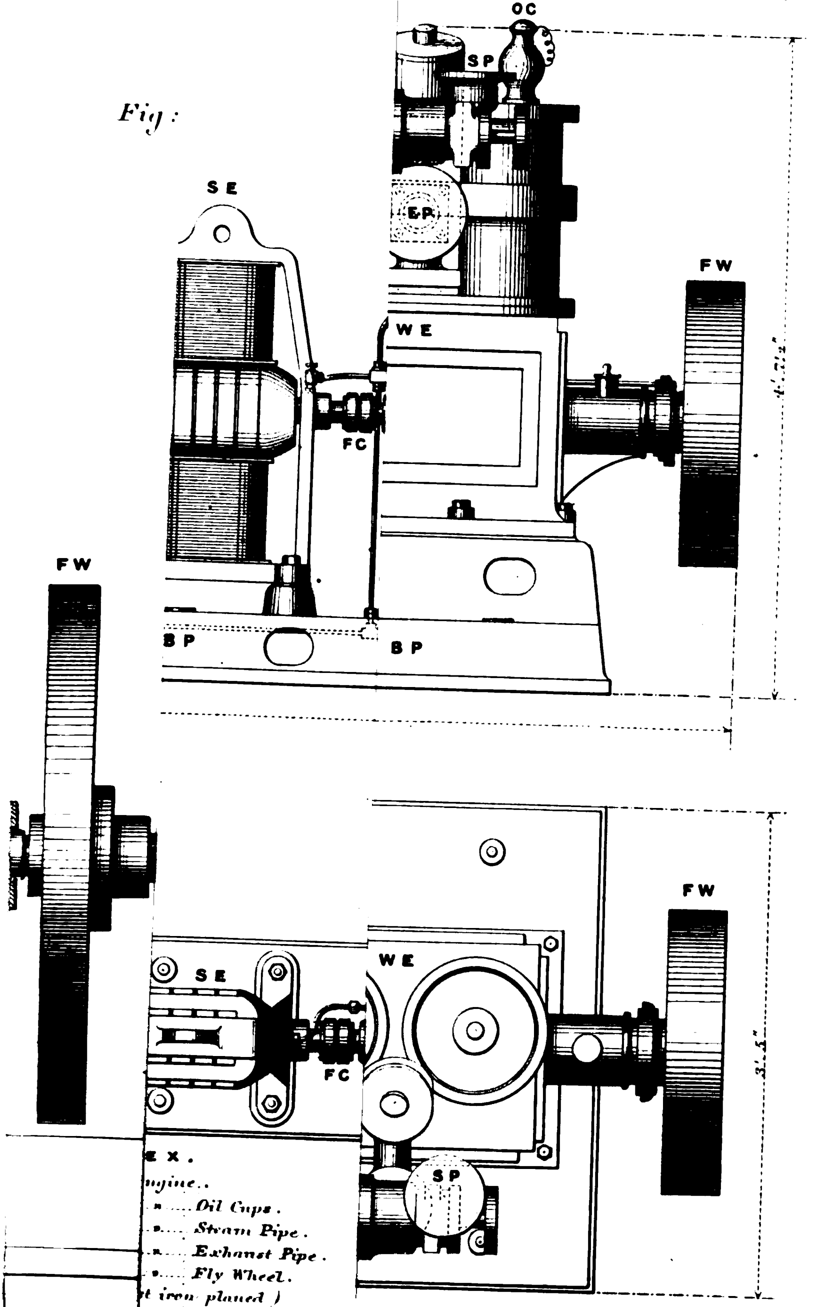
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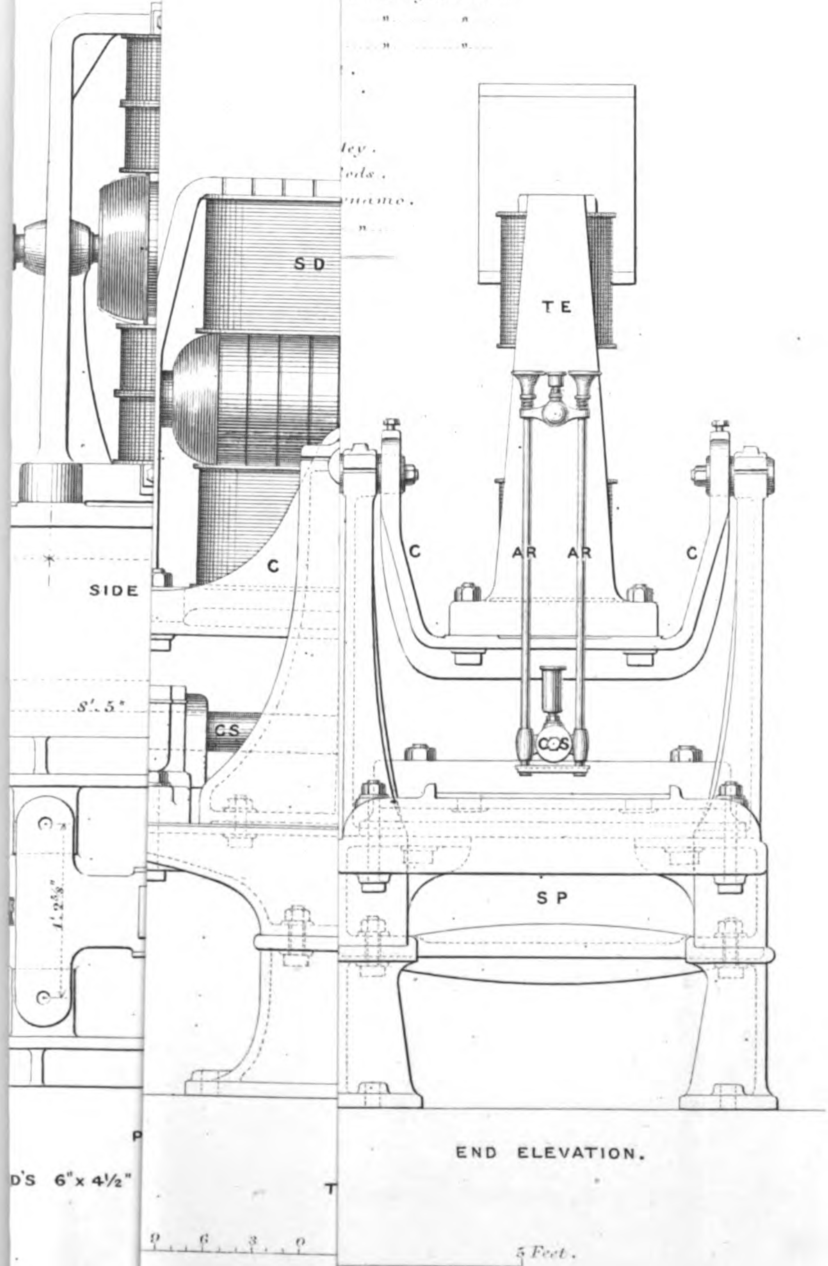
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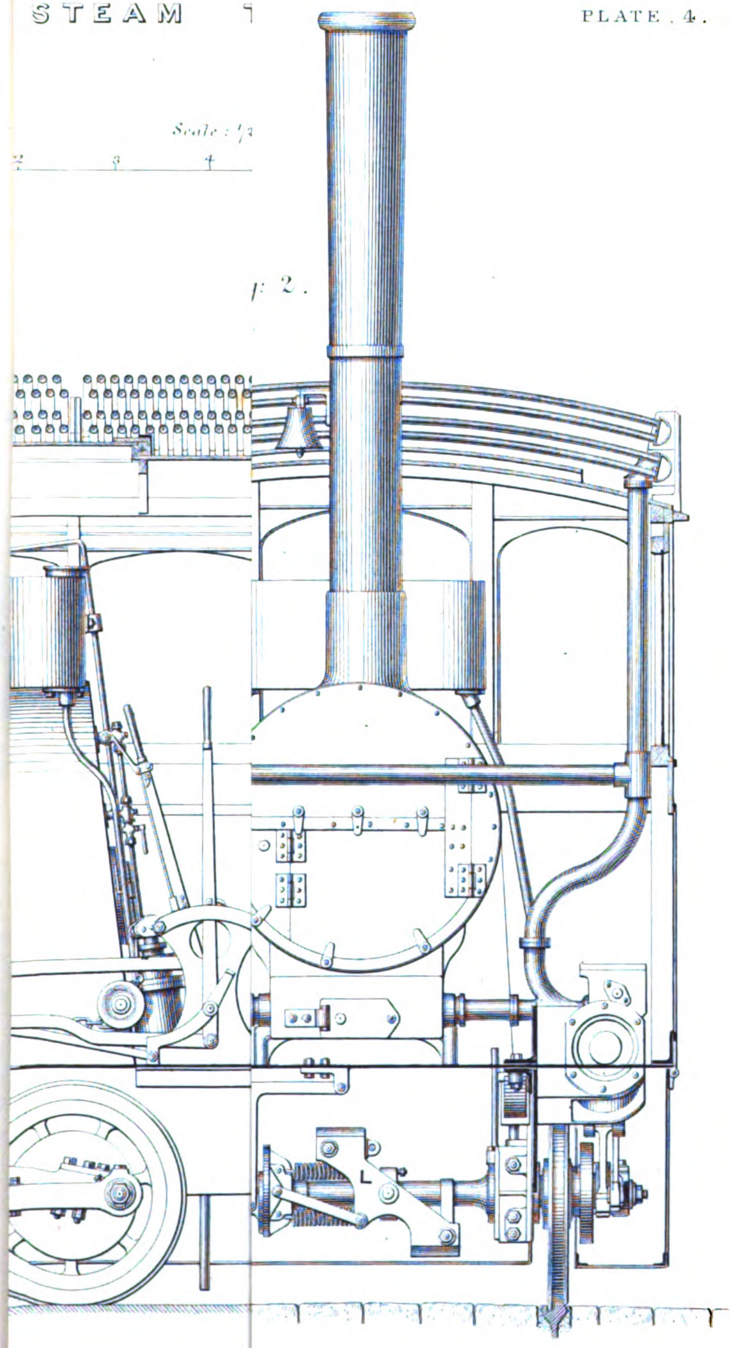
PLATE. 4.

Scale : 1/

g. 2.



CROSS SECTION.

of The Institution of C

THOS KELL & SON, LITH. 40, KING ST COVENT GARDEN.

PLATE. 5.

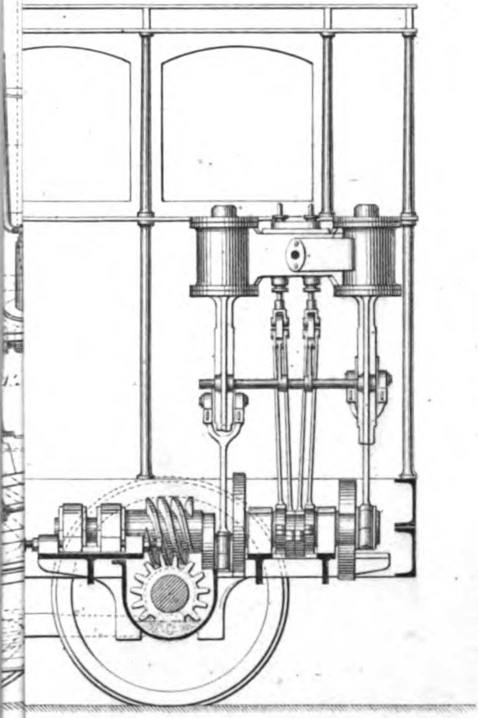
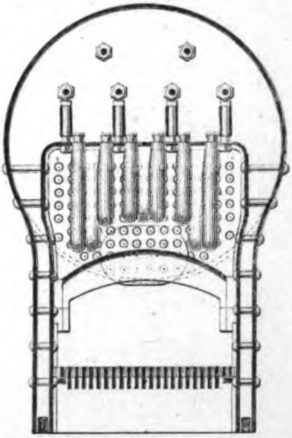


Fig: 4.



EVATION.

CROSS SECTION.

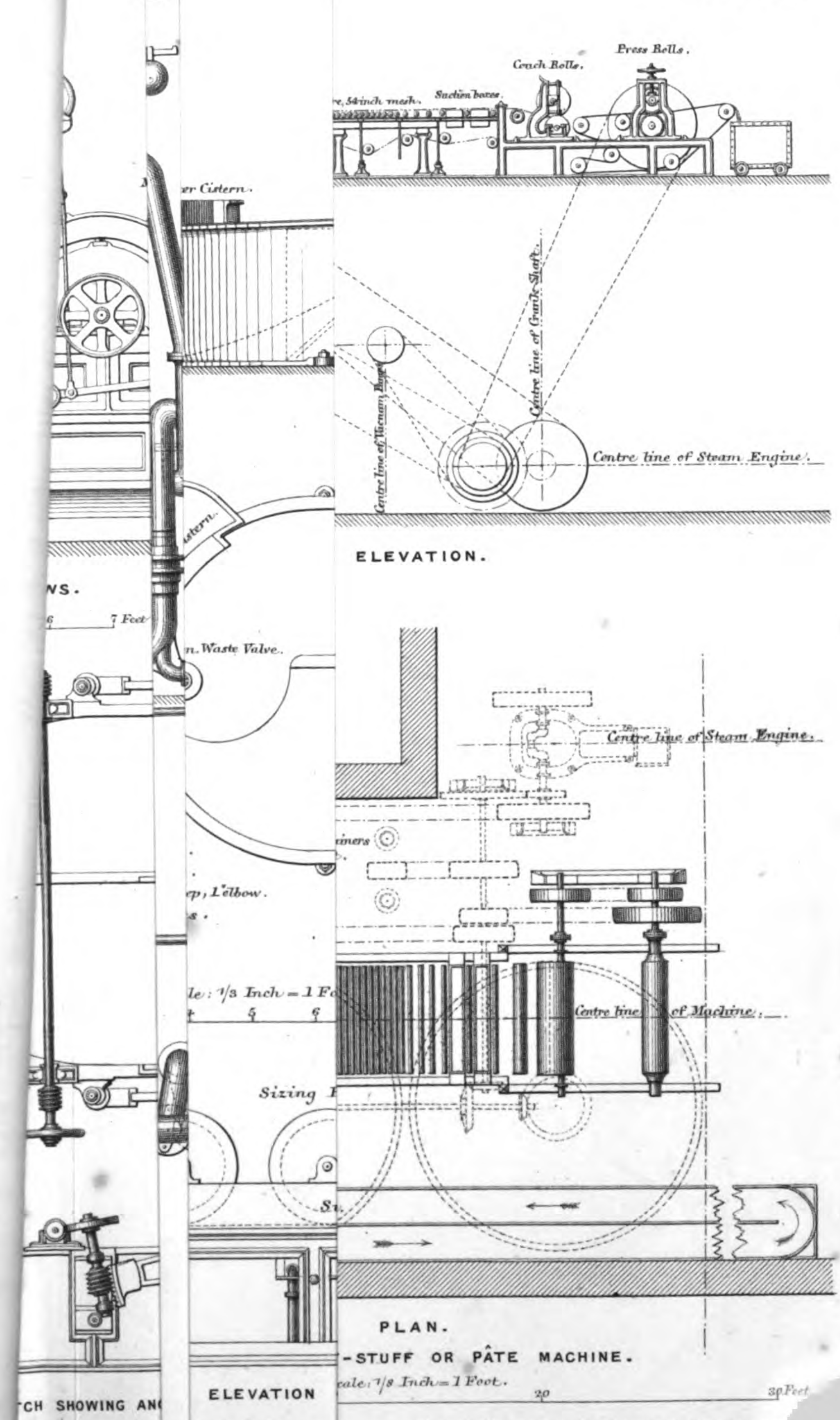
WORM-GEARED TRAMWAY LOCOMOTIVE.

Scale, 3/8 Inch = 1 Foot.

2 3 4 5 6 7 Feet

THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.

PLATE. 6.


Press Rolls.
Couch Rolls.
re, 54 inch mesh.
Suction boxes.
er Cistern.
Centre line of Crank Shaft.
Centre line of Vacuum Pump.
Centre line of Steam Engine.
istern.
WS.
6
7 Feet
n. Waste Valve.
Centre line of Steam Engine.
iners
ep, L elbow.
le: 1/3 Inch = 1 Fo
4
5
6
Centre line of Machine.
Sizing
Su
TCH SHOWING AN
ELEVATION

ELEVATION.

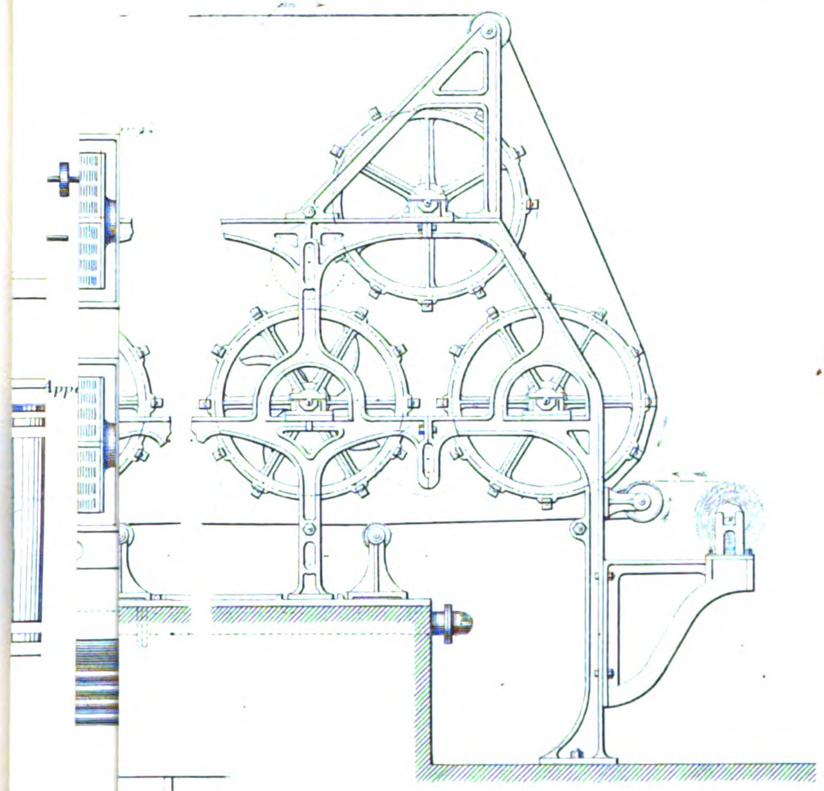
PLAN.

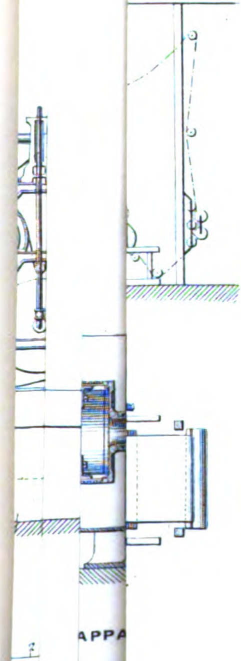
-STUFF OR PÂTE MACHINE.

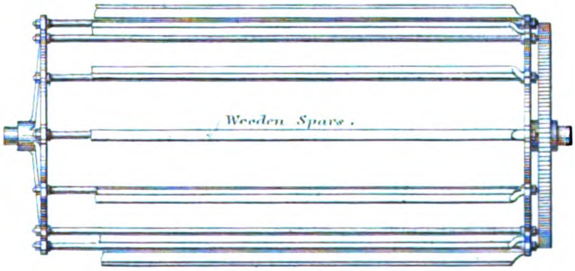
cale: 1/8 Inch = 1 Foot.

20 30 Feet

THOS KELL & SON, LITH 40, KING ST COVENT GA






Wooden Spars.

ELEVATION OF DRUM OF DRYING MACHINE Nº. 1.

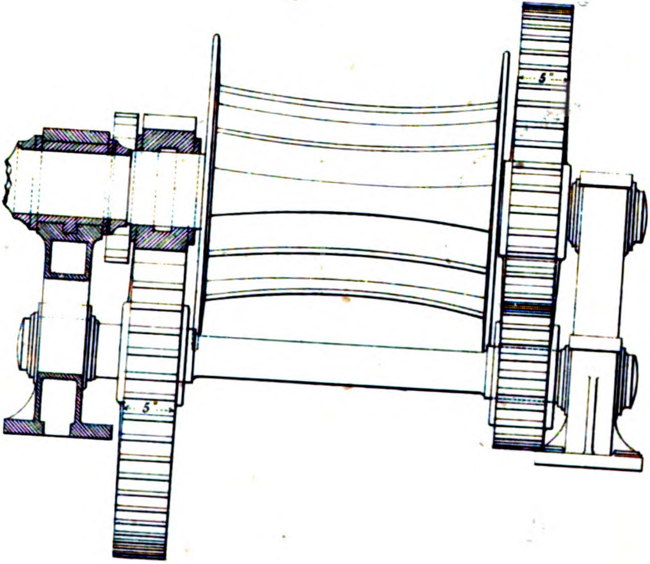
Scale: $3/8$ Inch = 1 Foot.

Ins. 12 6 0 1 2 3 4 5 6 Feet

THOS. KELL & SON, LITH. 40, KING ST. COVENT GARDEN.

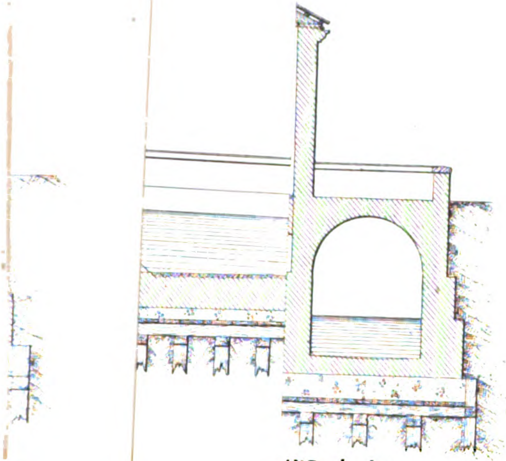
PLATE 8

Fig. 2.

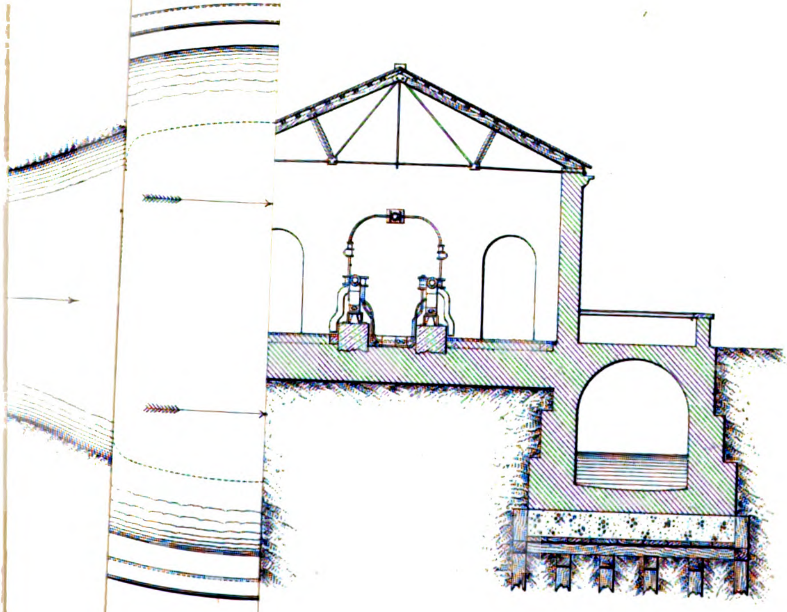


Scale, ⅔ Inch = 1 Foot.

THOS KELL & SON, LITH LONDO



INE I. L.



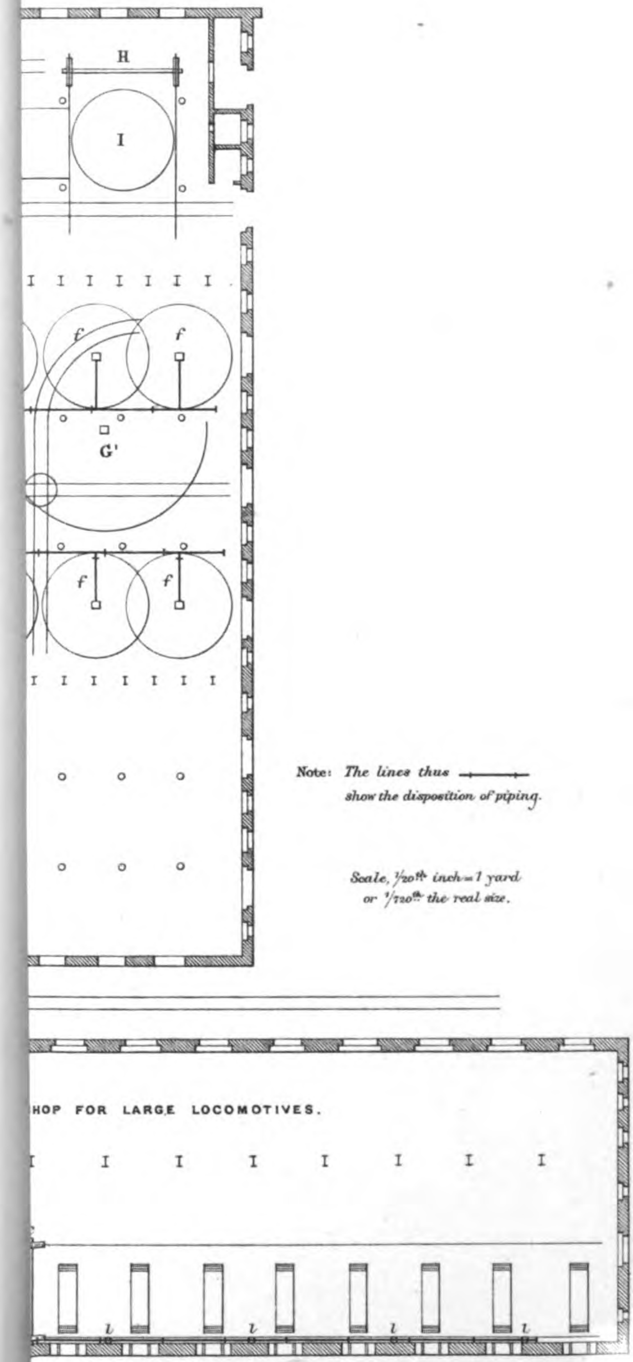
85.

SECTION THROUGH THE LINE G. H.

HOS KELL & SON, LITH 40 KING ST COVE

G APPARATUS

HE ERECTING SHOPS OF THE STÉ COCKERILL SERAING.

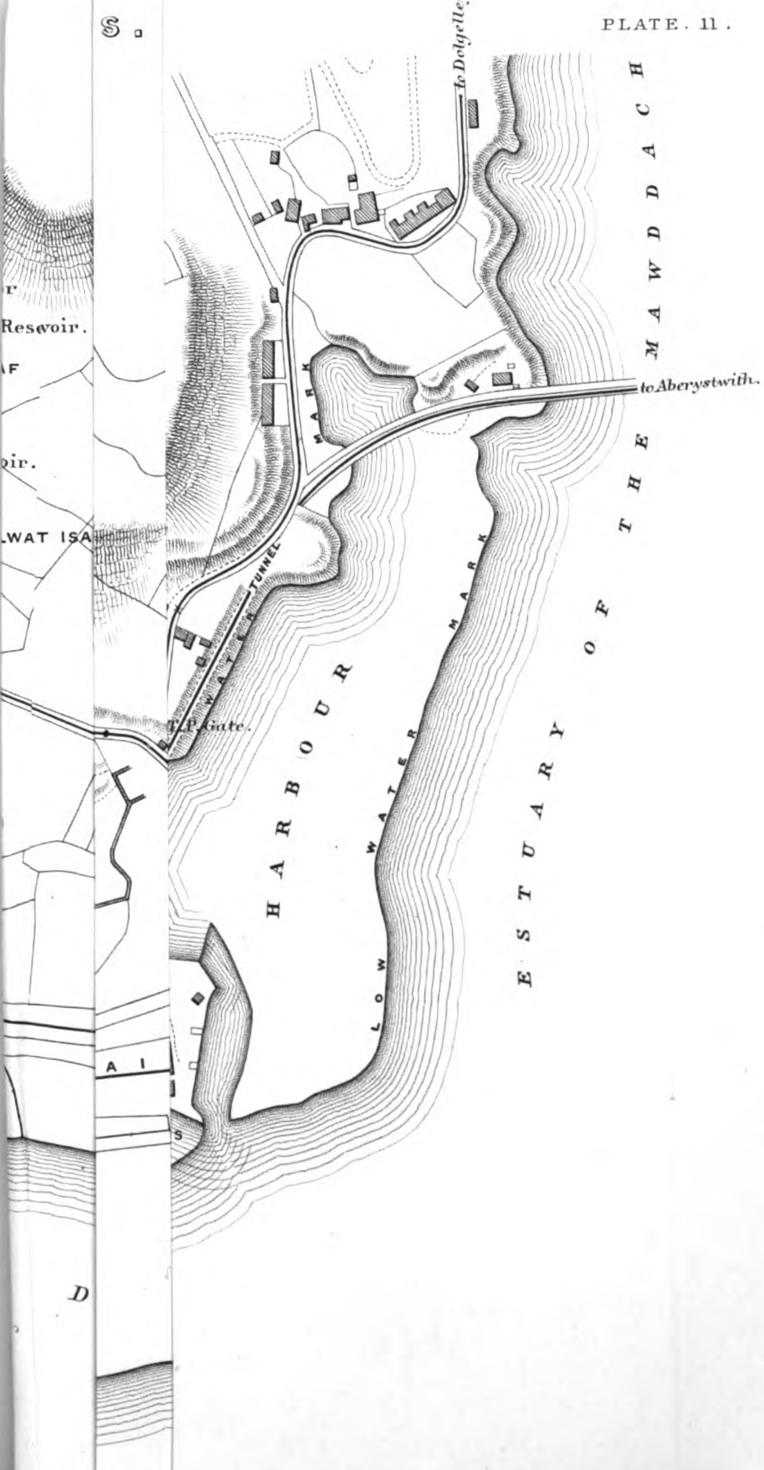

H
I
f
f
G'
f
f
HOP FOR LARGE LOCOMOTIVES.
l
l
l
l

Note: *The lines thus* ⟷ *show the disposition of piping.*

Scale, 1/20th inch = 1 yard or 1/720th the real size.

THOS KELL & SON.

PLATE. 11.


S.
to Dolgelley.
ESTUARY OF THE MAWDDACH
to Aberystwith.
MARK
HARBOUR
LOW WATER MARK
WATER TUNNEL
T.P. Gate.
r
Resevoir.
AF
oir.
LWAT ISA
AI
S
D
. Session

THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.